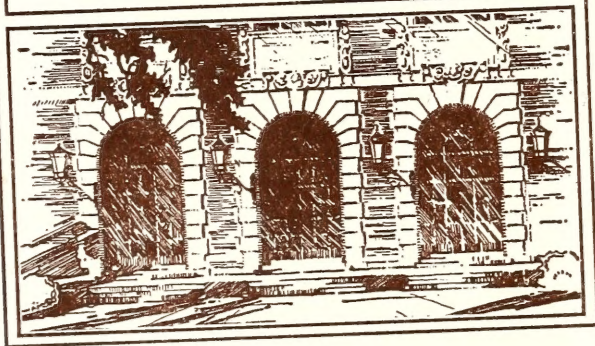


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The Coccidian Parasites (Protozoa, Sporozoa) of Ruminants

NORMAN D. LEVINE and VIRGINIA IVENS

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INTRODUCTION

Coccidia are among the commonest parasites of ruminants, and coccidiosis is an important disease of domestic sheep, cattle, and goats. The great majority of ruminant coccidia belong to the genus *Eimeria*, while a few belong to the genus *Isospora*. However, the literature on these coccidia is scattered and some papers have not been carefully evaluated. Of the two recent reviews of coccidia, Davies, Joyner and Kendall (1963) devoted 34 pages and Pellérdy (1965) 68 pages to those of ruminants. Kheisin (Cheïssin) (1967) discussed those in domestic ruminants briefly, and Pout (1969) reviewed coccidiosis of sheep. Neither included all the species given in this monograph, and none discussed them all completely.

Often in the past, authors who found coccidia in wild ruminants have simply assigned them to species known in domestic ruminants; this practice is not acceptable. Cross-infections experiments (Table 12) indicate that coccidia are rarely transmissible from one host genus to another, even though they may look very much alike. An organism that will not infect a given host is not a parasite of that host. Consequently, it should not be given the same name as an organism occurring in another host genus without proof of cross-infectibility. This principle has been followed wherever feasible in the present monograph. The coccidia of sheep and goats (*Ovis* and *Capra*) and those

of cattle and water buffaloes (*Bos* and *Bubalus*) are exceptions; in most cases the state of our knowledge does not permit clear-cut separation, at least at this time.

The present monograph gives a critical analysis of the coccidia of all ruminants, both wild and domestic. The known information on all species is assembled, so that this work should serve as a reference point for future studies on coccidia of ruminants.

The taxonomy, life cycle, oocyst structure, criteria for separation of coccidian species, and their general pathogenicity have been described by Levine and Ivens (1965), and there is no need to repeat this information here.

The genera of coccidia are taken up separately below. Within each protozoan genus, the species are arranged according to host genus. The ruminant classification used is primarily that of Simpson (1945), with some of the modifications introduced by Frechkop (1955). At the end of the monograph, the principal structural characteristics of the oocysts of each species are tabulated.

GENUS *EIMERIA* SCHNEIDER, 1875

This genus is characterized by the presence of four sporocysts, each containing two sporozoites, in each oocyst. The synonymy of this genus has been given by Pellérdy (1963).

Host Suborder RUMINANTIA

Host Superfamily TYLOPODA

Host Family CAMELIDAE

Eimeria cameli (Henry and Masson, 1932)

Reichenow, 1952

(PLATE 1, FIGS. 1 and 2; PLATE 2, FIGS. 5-8; PLATE 3, FIGS. 9-12)

Globidium cameli Henry and Masson, 1932a of Enigk, 1934.

Eimeria (*Globidium*) *cameli* (Henry and Masson, 1932a) Reichenow, 1952 of Abdussalam and Rauf, 1957.

Eimeria kazachstanica Tsygankov, 1950.

Eimeria casahstanica [sic] Zigankoff, 1950 of Pellérdy, 1965.

Eimeria noelleri (Henry and Masson, 1932) Pellérdy, 1956 of Dubey and Pande, 1964.

[non] *Eimeria cameli* Nöller, 1933 of Iwanoff-Gobzem, 1934; of Yakimoff and Matschoulsky, 1939; and of Tsygankov, 1950.

[non] *Eimeria* (?) *nölleri* Rastegaieff, 1930.

Description. This species was described briefly by Henry and Masson (1932a) and redescribed and named by the same authors (1932b, 1932c). They found it in a dromedary which died in Alfort, France, in 1931. They first found the parasite in scrapings from the mucosa and then in sections of the posterior ileum. Oocysts truncate ovoid, 81-100 by 63-94 μ , with a wall 10.4-15.6 μ thick. Micropyle 10-14 μ wide at the narrow end of the oocyst, covered by a clear part of the wall which does not form a cap. Oocyst wall apparently composed of 2 layers lined by a membrane. (Enigk, 1934, saw 3 layers.) Oocyst wall colorless at first, then becoming brown and so opaque that the development of its contents cannot be followed. Henry and Masson saw no sporulated oocysts and were unable to produce sporulation.

The oocysts described by Tsygankov (1950) under the name *Eimeria kazachstanica* were piriform, 75-95 by 55-70 μ with a mean of 87.3 by 64.0 μ , with a prominent micropyle 10-17.5 μ in inside diameter at the small end, with a yellow-green or dark brown, smooth, 3-layered wall 5-9 μ thick, the outer layer being transparent, the middle one yellow-green or dark brown, and the inner one dark green. Tsygankov followed oocyst sporulation. Oocyst residuum absent, oocyst polar granule present or absent, sporocysts elongate, pointed at both ends, without Stieda body, 40-50 by 14.5-20 μ with a mean of 45 by 18 μ . Sporocyst residuum present, composed of scattered granules and described as containing 2 inclusion bodies. Sporozoites described as sausage-shaped, 13-14.5 by 6-7 μ . However, we suspect that the structures which Tsygankov thought were sporozoites were actually clear globules at one end of each sporozoite, that the structures which he described as inclusion bodies 3.75-5 μ in diameter were actually the sporozoite nuclei, and that he failed to see the sporozoites themselves.

Dubey and Pande (1964) found a single oocyst 67 by 57 μ in a dromedary calf in India.

Sporulation Time. According to Tsygankov (1950), sporulation of *E. kazachstanica* took 10-15 days at 16-20 C.

Schizogony and Gametogony. Henry and Masson (1932b) found spherical or ellipsoidal structures up to 350 μ in diameter in the mucosa of the small intestine which they considered to be schizonts. They had a simple, lamellar outer membrane which was usually very thin, so thin that the largest schizonts were somewhat irregular in shape; in some cases a host cell nucleus up to 50 μ long was present and the membrane was thickened. The contents of these structures were of 2 types. Most often they consisted of very fine granules whose nature was hard to determine. In other cases there were spherules

(blastophores) 20-23 μ in diameter distributed in the contents; these spherules stained strongly and were surrounded by a colorless, refractile zone. The second type they considered to be microgametocytes because smears from them contained cells believed to be microgametes which were about 6 μ long and 0.5 μ wide.

Enigk (1934) found schizonts and microgametocytes up to 200 by 150 μ with a wall less than 1 μ thick. The earliest stages could not be differentiated. Cells with 4-8 nuclei were seldom found, and cells 14 μ in diameter already had 12 nuclei 1.5-2.0 μ in diameter. After further multiplication, the nuclei lay in rings or bands and formed so-called blastophores. These blastophores coalesced in part so that there remained in many cysts only a few large irregularly shaped blastophores. At this stage the microgametocytes and schizonts could be differentiated. The nuclei of each blastophore were squarish, 1 μ long, and arranged around the periphery of a central residual mass. Merozoites 2 μ long then formed; they were elongate, with a blunt end and a pointed one. In the microgametocytes the blastophores did not coalesce so much; they were generally small, had uniformly staining microgametes 3.0-3.5 μ long around their periphery, and had a central residual mass. Mature microgametocytes were much more numerous than mature schizonts.

Enigk (1934) found macrogametes in the ileum beginning 3 m behind the pylorus; their number decreased markedly near the large intestine; there were a few in the cecum, but none in the colon. The youngest stages were in the epithelial cells at the base of the glands. They were 4-5 μ in diameter, with nuclei 2 μ in diameter; a nucleolus was present. The infected epithelial cells were markedly enlarged and 22-28 μ in diameter; their nuclei were flattened and lay against the parasites. As the infected cells grew, they migrated out of the epithelial layer and finally lay beneath the epithelium in the tunica propria. They formed a wall not more than 3 μ thick. The host cell nuclei enlarged markedly after the cells left the epithelial layer, and 2-8 nucleoli could be found in a single section. The macrogametes began to differentiate when they reached a diameter of 12 μ . Their cytoplasm became vacuolated and later eosinophilic, a second nucleolus formed in the nucleus (which was now 4 μ in diameter), spheres staining golden yellow with iron hematoxylin formed in the outer zone, and outside them strongly eosinophilic granules formed. The spheres coalesced, and, when the parasite was 45 x 40 μ , formed a layer on its periphery. Enigk found few oocysts in the mucosa, and those that he saw were not quite as large as those seen by Henry and Masson (1932a).

Prepatent Period. Unknown.

Type Host. *Camelus dromedarius* (dromedary).

Other Hosts. *Camelus bactrianus* (Bactrian camel).

Location. Small intestine.

Geographic Distribution. USSR (Kazakhstan, Urals), Europe (France — veterinary school), Pakistan, India (Rajasthan).

Pathogenicity. Henry and Masson (1932a) thought that this species was pathogenic, producing a toxin, but Enigk (1934) found no evidence of pathogenicity.

Cross-Transmission Studies. None.

Prevalence. Abdussalam and Rauf (1957) found this species in 25% of 24 *C. dromedarius* in Pakistan.

Remarks. See *Remarks* under *E. bactriani* for an explanation of the nomenclature of this species.

***Eimeria dromedarii* Yakimoff and Matschoulsky, 1939**

(PLATE 1, FIGS. 3 and 4)

Eimeria cameli Nöller, 1933 *pro parte* of Iwanoff-Gobzem, 1934 *pro parte*.

Eimeria cameli Iwanoff-Gobzem of Tsygankov, *pro parte*.

? *Eimeria cameli* Jakimov, 1934 of Ryšavý, 1954.

Description. Oocysts ovoid; 100 oocysts measured by Yakimoff and Matschoulsky (1939) were 23-33 by 20-25 μ with a mean of 27.7 by 23.2 μ . One hundred oocysts measured by Dubey and Pande (1964) were 26-28 by 21-23 μ with a mode of 27 by 21 μ . Oocyst wall brown, 0.8-1.4 μ thick, "double-contoured" (2-3 μ thick, composed of 2 layers, according to Dubey and Pande, 1964). Oocyst wall thickened to form a kind of a "cap" 7-8 μ wide and 2-3 μ high. Yakimoff and Matschoulsky (1939) said, "As the cytoplasm contracts the oocyst membrane is seen to be coloured light pink or yellow." Sporocysts ovoid or spherical, 8.5-10.5 by 6.5-8.4 μ (10-11 by 8.5 μ according to Dubey and Pande, 1964), without Stieda bodies, each containing 2 comma-shaped sporozoites with one or 2 clear globules each. Oocyst and sporocyst residua absent. Oocyst polar granule absent.

Sporulation Time. Fifteen to 17 days at 10-12 C in 2% potassium bichromate solution.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Camelus dromedarius* (dromedary).

Other Hosts. *Camelus bactrianus* (Bactrian camel).

Location. Unknown.

Geographic Distribution. USSR (Leningrad Zoo), India (Rajasthan), Pakistan.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Dubey and Pande (1964) found this species in 44% of 45 dromedary camel calves less than 10 months old in Rajasthan, India. Abdussalam and Rauf (1957) found it in 4% of 24 *C. dromedarius* in Pakistan.

Remarks. Nöller (1933), Iwanoff-Gobzem (1934) and Yakimoff (1935a) apparently saw some *E. dromedarii* among the coccidia that they called *E. cameli* (a synonym of *E. bactriani*). Yakimoff and Matschoulsky (1939), however, described *E. dromedarii* and differentiated it from *E. bactriani*. Tsygankov (1950) thought they were the same, but Pellérdy (1965) reaffirmed their difference.

This is probably the species that Ryšavý (1954) reported from *C. bactrianus* in Czechoslovakia under the name "*Eimeria cameli*, Jakimov 1934." Ryšavý said that its oocysts were broadly ellipsoidal, 23-32 by 18-25 μ with a mean of 27 by 20 μ , thin-walled, with a micropyle and micropylar cap, and that its sporocysts were spherical, 8 μ in diameter, with coarsely granular protoplasm and a small sporocyst residuum; its sporulation time was 64 hours.

Eimeria pellerdyi Prasad, 1960 Emend. Pellérdy, 1965

(PLATE 4, FIG. 13)

Eimeria pellerdei Prasad, 1960.

Description. Oocysts oval or ellipsoidal, 22.5-24 by 12-13.5 μ with a smooth, colorless wall composed of 2 layers, without micropyle. Oocyst residuum and oocyst polar granule absent. Sporocysts ovoid, 9-10.5 by 4.5-6 μ , with a small Stieda body and a sporocyst residuum. Sporozoites club-shaped, 8-9.5 by 1.5-3 μ , with a central nucleus and a globule at the large end.

Sporulation Time. According to Prasad (1960), complete sporulation required about 5 days, presumably at room temperature.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Camelus bactrianus* (Bactrian camel).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. London Zoo.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Eimeria rajasthani Dubey and Pande, 1963

(PLATE 4, FIGS. 14 and 15)

Description. Oocysts nearly ellipsoidal, 34-39 by 25-27 μ with a mode of 36 by 25 μ . Oocyst wall 2-3 μ thick, composed of 2 layers, the outer one relatively thick and light yellowish green, the inner one darker, with a shining inner contour. Micropyle not visible but apparently present. Micropylar cap present, 8-11 μ wide and 2-3 μ high. Oocyst polar granule absent. Oocyst residuum absent. Sporocysts almost ovoid, with Stieda body, 14-15 by 8-11 μ with a mode of 15 by 11 μ . Sporocyst residuum present. Sporozoites elongate with one end broad and the other narrow and pointed, lying lengthwise head to tail in sporocysts, 10-14 by 3-4 μ , containing 2 or sometimes more globules.

Sporulation Time. According to Dubey and Pande (1963, 1964), sporulation took about a week at room temperature.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Camelus dromedarius* (dromedary).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. India.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Dubey and Pande (1963) found this species in 62% of 45 camel calves less than 10 months old in Rajasthan, India.

Eimeria bactriani n. sp.

(PLATE 4, FIGS. 16-19)

Eimeria cameli Nöller, 1933.

Eimeria cameli Nöller, 1932 emend. Yakimoff and Matschoulsky, 1939 of Pellérdy, 1965.

Eimeria cameli Iwanoff-Gobzem, 1934; Yakimoff, 1935a; Tsyganov, 1950.

? *Eimeria nolleri* Reichenow, 1953 of Abdussalam and Rauf, 1957.

[non] *Eimeria cameli* (Henry and Masson, 1932a) Reichenow, 1953.

[non] *Eimeria noelleri* (Henry and Masson, 1932a) Pellérdy, 1956.

[non] *Globidium cameli* Henry and Masson, 1932a.

Description. According to Nöller (1933) the oocysts are spherical to ellipsoidal, about 32 μ long and 25-27 μ wide; micropyle present, but micropyle cap normally absent (those few oocysts with micropyle caps which Nöller saw were undoubtedly not *E. bactriani*); oocyst residuum absent; oocyst wall light yellowish to yellowish brown; sporocysts about 15-17 μ long and about 10 μ wide. The oocysts described by Iwanoff-Gobzem (1934) as those of *E. cameli* were spherical to short oval, with a double-contoured wall (illustrated as composed of one layer), 23-34 by 20-30 μ with a mean of 28.3 by 25.5 μ without a micropyle, with an oocyst polar granule, without an oocyst residuum, with round or elongate sporocysts 8-9 by 6-9 μ , with a sporocyst residuum and with lemon-shaped sporozoites. Yakimoff (1935) described both oval and spherical oocysts, both of which he assigned to "*E. cameli*." Later, however, Yakimoff and Matschoulsky (1939) said that only the spherical oocysts were "*E. cameli*," the oval ones belonging to their new species *E. dromedarii*. The spherical oocysts seen by Yakimoff (1935a) were 21-29 μ in diameter with a mean of 23.5 μ ; they were about $\frac{1}{5}$ as common as the oval ones. Tsygankov (1950) found oocysts measuring 22.5-30 by 20-27.5 μ with a mean of 26 by 23.7 μ ; these he said corresponded in structure to Iwanoff-Gobzem's *E. cameli*; however, he also found oocysts which he said corresponded to Yakimoff and Matschoulsky's *E. dromedarii*, and he said that the latter was a synonym of the former.

Sporulation Time. Nöller (1933) said that sporulation took 10 days at room temperature. Yakimoff (1935a) said that the oocysts sporulated in 6 days and Tsygankov (1950) that they sporulated in 6-8 days at room temperature or 3 weeks at 10-12 C.

Schizogony and Gametogony. According to Enigk (1934), *E. cameli* occurred in the small intestine beginning about 2 m behind the pylorus and extending into the ileum. The epithelial cells of the villi were invaded. The schizonts were surrounded by a clear zone within the host cell. The schizonts were 16 by 10 μ and contained 20-24 merozoites each 9 by 2 μ .

The microgametocytes were also in the epithelial cells of the villi in the small intestine. They reached a diameter of 14 μ or 12 by 19 μ . They contained several centers of development, each with a residual body. The mature microgametes were 4 μ long. The mature macrogametes were 25 by 20 μ , and were often free in the gut lumen.

Prepatent Period. Unknown.

Type Host. *Camelus bactrianus* (Bactrian camel).

Other Hosts. *Camelus dromedarius* (dromedary).

Location. Small intestine, beginning about 2 m behind the pylorus and extending into the ileum.

Geographic Distribution. USSR.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown. This species is apparently quite common, but the information given by Yakimoff (1935a) and Tsygankov (1950) is for a combination of this species and *E. dromedarii*.

Remarks. This species was first reported by Nöller (1933) as *E. cameli* in Bactrian camels from a group brought into Germany from the Urals. Iwanoff-Gobzem (1934), Yakimoff (1935a) and Tsygankov (1950) found the same species in Bactrian camels and dromedaries in various parts of the USSR. Enigk (1934) also found it in a Bactrian camel brought into Germany from the Urals. However, this form was not the same as the "*Globidium*" *cameli* described by Henry and Masson (1932a) from a dromedary in France. Since *Globidium* is now accepted as a synonym of *Eimeria* (see Reichenow, 1952), we are faced with two different species of *Eimeria*, both assigned to the species *cameli*. Pellérdy (1965) attempted to rectify the situation by calling Henry and Masson's (1932a) species *E. noelleri*; however, since these authors used the name *cameli* first, their name takes precedence. Hence, *E. noelleri* falls as a synonym of *E. cameli* (Henry and Masson, 1932a). The next problem is to determine the correct name for the "*E. cameli*" of Nöller (1933) and Iwanoff-Gobzem (1934). Pellérdy (1965) retained the name *Eimeria cameli* Nöller, 1932 emend. Yakimoff and Matschoulsky, 1939 but this action cannot stand. We are therefore proposing a new name, *Eimeria bactriani* n. sp., for it.

This is probably the species reported by Abdussalam and Rauf (1957) under the name "*E. nolleri* Reichenow 1953" from 12% of 24 *C. dromedarius* in Pakistan.

Eimeria peruviana Yakimoff, 1934

(PLATE 6, FIG. 31)

Description. Oocysts described as oval and illustrated as ellipsoidal, 28-37.5 by 18-22.5 μ with a mean of 31.8 by 19.3 μ . Micropyle absent. Oocyst wall stated to have a double membrane but illustrated with a single-layered wall. Oocyst polar granule absent. Oocyst residuum present. Sporocysts illustrated as more or less ellipsoidal, without Stieda body, 10.5-15 by 7.5 μ . Sporocyst illustrated with granules within the sporozoites which might or might not have been sporocyst

residual granules. Sporozoites elongate, illustrated as lying lengthwise in sporocysts.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Lama glama* (llama).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. USSR (presumably in a zoo).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff (1934) found this species in 1 of 5 llamas.

Eimeria alpaca Guerrero, 1967

(PLATE 5, FIG. 21)

Description. Oocysts ellipsoidal, rarely ovoid, 22-26 by 18-21 μ with a mean of 24.1 by 19.6 μ . Oocyst wall smooth, composed of 2 layers with a total thickness of 1.2-1.6 μ with a mean of 1.45 μ ; outer layer 1.1 μ thick, very pale greenish to bluish; inner layer 0.4 μ thick, appearing as a dark yellow line, rarely somewhat wrinkled at the micropylar end. Micropyle present. Micropylar cap present, colorless to pale greenish, 0.7-1.3 μ high and 4.4-7.5 μ wide with a mean of 1.0 by 5.7 μ . Oocyst polar granule present or absent; 1-3 polar granules seen in 31% of 55 oocysts. Oocyst residuum absent. Sporocysts ovoid, rounded at both ends, with one end broader than the other, 10-13 by 7-8 μ with a mean of 11.0 by 6.8 μ . Stieda body very faintly perceptible. Sporocyst wall about 0.2 μ thick. Sporocyst residuum present, usually consisting of a few granules forming a compact mass about 1.4 μ in diameter. Sporozoites elongate, with one end narrower than the other, lying lengthwise head to tail in sporocysts. Sporozoites with 1-3 clear globules.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Lama pacos* (alpaca).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. South America (Peru).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Guerrero (1967) found this species in 9 of 12 alpacas from Peru.

Eimeria lamae Guerrero, 1967

(PLATE 5, FIG. 20)

Description. Oocysts ellipsoidal, occasionally ovoid, slightly flattened at micropylar end, which is sometimes the smaller one. Oocyst wall smooth, composed of 2 layers 1.4-1.8 μ in total thickness with a mean of 1.7 μ ; outer layer 1.3 μ thick, bluish to greenish yellow; inner layer 0.5 μ thick, brownish-yellow, sometimes somewhat wrinkled at micropylar end. Sporulated oocysts 30-40 by 21-30 μ with a mean of 35.6 by 24.5 μ . Micropyle present. Micropylar cap prominent, dome-shaped, colorless to light grayish, 1.5-2.2 μ high and 9-11 μ wide with a mean of 1.8 by 9.9 μ . Oocyst polar granule present or absent; one or more seen in 26% of 70 sporulated oocysts. Oocyst residuum absent. Sporocysts elongate ovoid, rounded at both ends, with one end broader than the other, with a Stieda body and a wall about 0.25 μ thick. Sporocysts 13-16 by 8-10 μ with a mean of 15.2 by 8.5 μ . Sporocyst residuum usually consisting of a few granules forming a compact mass about 2 μ in diameter. Sporozoites elongate, with one end narrower than the other, lying lengthwise head to tail in sporocysts. Sporozoites with 1-3 clear globules.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Lama pacos* (alpaca).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. South America (Peru).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Guerrero (1967) found this species in 3 out of 12 alpacas from Peru.

Eimeria punoensis Guerrero, 1967

(PLATE 5, FIG. 22)

Description. Oocysts ellipsoidal, occasionally ovoid (when ovoid, slightly broader at micropylar end), 17-22 by 14-18 μ with a mean of 19.9 by 16.4 μ . Oocyst wall smooth, composed of 2 layers 0.8-1.1 μ in total thickness with a mean of 1.0 μ ; outer layer 0.7 μ thick, blue to

purplish; inner layer 0.3 μ thick, appearing as a dark line. Micropyle present. Micropylar cap present, flat, colorless, sometimes difficult to see, 0.4-0.8 μ high and 3.5-5.5 μ wide with a mean of 0.5 by 4.1 μ . Oocyst polar granule present or absent; 1-2 were seen in 24% of 58 sporulated oocysts. Oocyst residuum absent. Sporocysts somewhat elongate ovoid, rounded at both ends, with one end broader than the other, 8-11 by 5-7 μ with a mean of 9.2 by 6.1 μ . Stieda body faintly perceptible. Sporocyst residuum present, usually consisting of a few granules forming a compact mass 1 μ in diameter. Sporozoites elongate, with one end narrower than the other, lying lengthwise head to tail in sporocysts. Sporozoites with 1-3 clear globules.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Lama pacos* (alpaca).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. South America (Peru).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Guerrero (1967) found this species in 11 out of 12 alpacas in Peru.

***Eimeria* sp. Guerrero, Hernandez and Alva, 1967**

Description. Oocysts piriform, brownish, 80-90 by 55-65 μ , with a thick wall. Micropyle present at small end.

Sporulation Time. Unknown. Oocysts did not sporulate.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Lama pacos* (alpaca).

Other Hosts. None.

Location. Ileum.

Geographic Distribution. South America (Peru).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown. Guerrero, Hernandez and Alva (1967) found this form in a single alpaca.

Host Suborder RUMINANTIA

Host Superfamily CERVOIDEA

Host Family CERVIDAE

Host Subfamily CERVINAE

Eimeria spp. Ryšavý, 1954

Eimeria arloingi Marotel, 1905 of Ryšavý, 1954 in *Dama dama*.

Eimeria crandallis Honess, 1942 of Ryšavý, 1954 in *Dama dama*.

Eimeria faurei Moussu and Marotel, 1901 of Ryšavý, 1954 in *Dama dama*.

Eimeria intricata Spiegl, 1925 of Ryšavý, 1954 in *Dama dama*.

Eimeria ninac-kohl-yakimovi Yakimoff and Rastegaieva, 1930 of Ryšavý, 1954 in *Dama dama*.

Eimeria parva Kotlan, Moezy and Vajda, 1929 of Ryšavý, 1954 in *Dama dama*.

Description. None.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Dama dama* (fallow deer).

Other Hosts. See Remarks.

Location. Oocysts in feces.

Geographic Distribution. Europe (Czechoslovakia).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Ryšavý (1954) reported the above 6 species of *Eimeria* as occurring in *Dama dama* in Czechoslovakia. The natural host of *E. arloingi* and *E. ninac-kohl-yakimovae* is the domestic goat and that of the others is the domestic sheep. Since Ryšavý did not describe any of the coccidia from the fallow deer, and since he attempted no cross-transmission experiments, it is impossible to give names to these fallow deer coccidia; it is extremely doubtful that they actually belonged to the species to which he assigned them.

Eimeria wassilewskyi Rastegaieff, 1930

(PLATE 5, FIG. 24)

Eimeria wassilewskyi Rastegaieff, 1930 (*lapsus*).

Eimeria wassilewskyi Rastegaieff, Yakimoff and Sokoloff, 1935 (*lapsus*) *pro parte*.

Eimeria wasielewskyi Rastegaieff. Pellérdy, 1963 (*lapsus*).

[non] *Eimeria wassilewskyi* [*sic*] Rastegaieff. Yakimoff and Sokoloff, 1935 (in *Cervus elaphus* and *Sika hortulorum*).

Description. Oocysts broadly ovoid, 29 by 28 μ with a very thick

double contoured wall almost $3.6\ \mu$ thick. Micropyle apparently present. Sporulated oocysts not described.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Axis axis* (syn., *Cervus axis*) (axis deer).

Other Hosts. None.

Location. Feces.

Geographic Distribution. Leningrad zoo.

Pathogenicity. One deer in which this species was found died with severe hemorrhagic diarrhea, and Rastegaieff believed that the cause of death was hemorrhagic coccidian enterocolitis. The small and large intestines were hyperemic and contained a large amount of bloody mucus and a few small ulcers.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Rastegaieff (1930) described this species from oocysts in the feces of a male axis deer in the Leningrad zoo. Although she assigned it to the genus *Eimeria*, she neither mentioned nor described the sporulated oocysts. Whether this is a valid species remains to be determined by future study.

Yakimoff and Sokoloff (1935) said that Yakimoff (1934) had found what they considered to be "*E. wassilewsky* Rastegaieff" in 1 out of 2 *Cervus elaphus* and 1 out of 4 *Sika hortulorum* (syns., *Pseudoaxis dybovskyi* or *P. hortulorum*) from Askania Nova, Ukraine. The oocysts in *C. elaphus* were ovoid, without a micropyle, and measured 21-30 by 18-24 μ with a mean of 28.0 by 20.8 μ . The oocysts in *S. hortulorum* were ovoid, without a micropyle, and measured 27 by 19.5-21 μ (apparently only 2 oocysts were measured). No other information was given. Neither of these forms is *E. wassilewskyi*; they differ from it in oocyst shape and in lacking a micropyle (which Rastegaieff's drawing indicated was present). What they are remains to be determined.

Eimeria (?) sp. Rastegaieff, 1930

Coccidium. Rastegaieff, 1930.

Description. Oocysts ovoid with one end flattened, 18 by 14 μ , with a distinct micropyle 4.5 μ in diameter. Sporulated oocysts not described.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Axis axis* (syn., *Cervus axis*) (axis deer).

Other Hosts. None.

Location. Feces.

Geographic Distribution. Leningrad zoo.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Rastegaieff (1930) found these oocysts once in the feces of an axis deer in the Leningrad zoo. She did not study them or attempt to assign them to a genus.

Eimeria cervi Galli-Valerio, 1927

[non] *Eimeria cervi* Galli-Valerio of Boch and Lucke, 1961.

Description. According to Galli-Valerio (1927), the oocysts were piriform, slightly flattened at the micropylar end, with a poorly visible micropyle, and 33 by 21 μ . The sporocysts were ovoid, 12 by 9 μ , with comma-shaped sporozoites measuring 3 by 2 μ .

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus elaphus* (red deer).

Other Host. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Switzerland).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. This species has been seen presumably only by Galli-Valerio (1927). Boch and Lucke (1961) described a form under this name from the red deer which was undoubtedly *E. robusta*. They synonymized *E. robusta* with *E. cervi*, basing this action on the fact that the rough, brownish outer layer of the oocyst wall of *E. robusta* is easily detached from the smooth, colorless inner layer, and that the oocyst then looks like what may have been that seen and sketchily described by Galli-Valerio (1927). However, since Galli-Valerio did not mention a rough, brownish outer layer, this conclusion cannot be substantiated.

***Eimeria gallivalerioi* Rastegaieff, 1930**

Description. Oocysts ovoid, 16-23 by 11-14 μ . The oocysts were said not to have sporulated. Nevertheless, in her table, Rastegaieff (1930) indicated that there was no oocyst residuum and that the sporocysts were piriform. No further description given.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus elaphus* (red deer).

Other Hosts. None.

Location. Feces.

Geographic Distribution. Leningrad zoo.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Rastegaieff (1930) described this species from 3 red deer in the Leningrad zoo. Although she said that the oocysts did not sporulate, she stated that *Isospora* had never been reported from ruminants and that she was therefore justified in assigning this species to the genus *Eimeria*.

***Eimeria asymmetrica* Supperer and Kutzer, 1961**

(PLATE 5, FIGS. 25 and 26; PLATE 6, FIGS. 27 and 28)

Description. Oocysts ellipsoidal, partially asymmetrical with one side a little flatter than the other, 25-32.5 by 15-18 μ (25-31 by 16-19 μ , according to Boch and Lucke, 1961), with one end slightly smaller than the other. Oocyst wall colorless to yellowish, illustrated as smooth and composed of a single layer. Micropyle present. Oocyst residuum and oocyst polar granule absent. Sporocysts ovoid, 8-10 by 6-7 μ , illustrated without Stieda body. Sporocyst residuum present. Sporozoites illustrated as elongate, lying lengthwise head to tail in sporocysts, with 1-2 clear globules.

Sporulation Time. Four days, according to Supperer and Kutzer (1961).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus elaphus* (red deer).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Austria, Germany).

Pathogenicity. Unknown.

Cross-Transmission Studies. Apparently none.

Prevalence. Unknown.

***Eimeria austriaca* Supperer and Kutzer, 1961**

(PLATE 5, FIG. 23, PLATE 10, FIG. 63)

Description. Oocysts ellipsoidal to broadly ovoid, 17-25 by 14-20 μ (19-22 by 15.5-19 μ according to Boch and Lucke, 1961), with a thin, smooth colorless wall illustrated as composed of a single layer. Micropyle absent. Oocyst residuum and oocyst polar granule absent. Sporocysts spindle-shaped, 10-12.5 by 5-6 μ , illustrated without a Stieda body. Sporocyst residuum absent. Sporozoites illustrated as elongate, lying lengthwise head to tail in sporocysts, with one or more clear globules.

Sporulation Time. Four to 5 days, according to Supperer and Kutzer (1961).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus elaphus* (red deer).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Austria, Germany).

Pathogenicity. Unknown.

Cross-Transmission Studies. Supperer and Kutzer (1961) were unable to transmit this species to the ox, sheep, or goat.

Prevalence. Unknown.

***Eimeria robusta* Supperer and Kutzer, 1961**

(PLATE 6, FIGS. 29 and 30; PLATE 7, FIGS. 35 and 36)

Eimeria cervi Galli-Valerio of Boch and Lucke, 1961.

Description. Oocysts ovoid, 31-42.5 by 22.5-30.5 μ (31-37 by 22-25 μ according to Boch and Lucke, 1961; 34-42 by 23.5-30 μ with a mean of 38.5 by 27.8 μ according to Jansen and van Haaften, 1966), with a wall 2.2-2.8 μ thick, composed of 2 layers, of which the outer one was brown, with a rough, granular surface, and could be easily separated from the smooth, colorless to yellowish inner layer after incubation in 1.5% potassium bichromate solution. Inner layer about 1 μ thick, often

slightly flattened at the small end. Micropyle present. Oocyst residuum absent. Oocyst polar granule present. Sporocysts elongate ovoid, 14-19 by 7-10 μ , illustrated without a Stieda body. Sporocyst residuum present. Sporozoites illustrated as elongate, lying lengthwise head to tail in sporocysts, with 2 clear globules each.

Sporulation Time. Four to 5 days, according to Supperer and Kutzer (1961); 5-6 days according to Jansen and van Haaften (1966).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus elaphus* (red deer).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Austria, Germany, Netherlands).

Pathogenicity. Unknown. Jansen and van Haaften (1966) found a mucous enteritis in a red deer calf which had died in the Netherlands; many oocysts of *E. robusta* were present, and they thought that this species had caused the death of the animal.

Cross-Transmission Studies. Supperer and Kutzer (1961) were unable to transmit this species to the ox, sheep, or goat.

Prevalence. Unknown.

Remarks. Boch and Lucke (1961) found what was undoubtedly this species in *C. elaphus* in Germany. They synonymized it with *E. cervi*, basing this action on the fact that the rough, brownish outer layer of the oocyst wall of *E. robusta* is easily detached from the smooth, colorless inner layer, and that the oocyst then looks like what may have been seen and sketchily described by Galli-Valerio (1927). However, since Galli-Valerio did not mention a rough, brownish outer layer, this conclusion cannot be substantiated. Jansen and van Haaften (1966), too, felt that Galli-Valerio's description was too sketchy to draw any conclusion about the relationship between these 2 forms.

Eimeria sordida Supperer and Kutzer, 1961

(PLATE 7, FIG. 37)

Description. Oocysts ellipsoidal to ovoid, 30-34 by 21-25 μ , with a thick, yellowish to yellowish brown wall, often rather rough, illustrated as composed of a single layer, almost always with fecal particles adhering to the wall. Micropyle and micropylar cap present. Oocyst residuum absent. Oocyst polar granule present. Sporocysts elongate ovoid, 12-13 by 7.5 μ . Sporocyst residuum present.

Sporulation Time. Four to 5 days according to Supperer and Kutzer (1961).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus elaphus* (red deer).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Austria).

Pathogenicity. Unknown.

Cross-Transmission Studies. Apparently none.

Prevalence. Unknown.

***Eimeria schoenbuchi* Boch, 1963**

(PLATE 6, FIGS. 32-34)

Description. Oocysts almost spherical, 53-62 μ in diameter with a mean of 59.1 μ . Oocyst wall brownish, 3.0-4.5 μ thick, composed of 2 layers, with a wavy, sticky surface. Micropyle absent. Oocyst residuum present. Oocyst polar granule apparently absent. Sporocysts elongate ovoid, later spindle-shaped, 26.5-28 μ long. Sporocyst residuum and Stieda body not mentioned. Sporozoites granular, lying lengthwise head to tail in sporocysts, illustrated with clear globules near the center and large end.

Sporulation Time. Five to 7 days in 1.5% potassium bichromate solution at 27 C according to Boch (1963).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus elaphus* (red deer).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Europe (Germany).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

***Eimeria elaphi* Jansen and van Haaften, 1966**

(PLATE 7, FIG. 38)

Description. Oocysts spherical or subspherical, 10-15 by 9.5-13 μ with a mean of 13.3 by 12.0 μ , with a smooth wall, illustrated as com-

posed of a single layer, without micropyle. Oocyst polar granule and oocyst residuum absent. Sporocysts 6-9.5 by 2.5-4 μ with a mean of 7.8 by 3.3 μ . Stieda body not mentioned. Sporocyst residuum present. Sporozoites elongate, lying lengthwise head to tail in sporocysts.

Sporulation Time. Eight days according to Jansen and van Haaften (1966).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus elaphus* (red deer).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Europe (Netherlands).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Eimeria sp. Yakimoff, 1935

Eimeria wassilewsky [sic] Rastegaieff of Yakimoff, 1935b (*pro parte*).

Description. Oocysts ovoid, without micropyle, 21-30 by 18-24 μ with a mean of 28.0 by 20.0 μ . No other structural information given.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus elaphus* (red deer).

Other Hosts. None.

Location. Feces.

Geographic Distribution. USSR (Ukraine).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff (1935b) found this form in one out of 2 *C. elaphus* from Askania Nova, Ukraine.

Remarks. Although Yakimoff (1935b) said that this form was "*Eimeria wassilewsky* Rastegaieff," it is not. It differs from *E. wassilewskyi* in oocyst shape and in lacking the micropyle which Rastegaieff's drawing indicated was present. In addition, it occurs in a different host genus. What it is remains to be determined, if this can be done at all on the basis of the meager information available. It could perhaps be *E. austriaca*.

Eimeria spp. Ryšavý, 1954

Eimeria arloingi Marotel, 1905 of Ryšavý, 1954 in *Cervus elaphus*.
Eimeria auburnensis Christensen and Porter, 1939 of Ryšavý, 1954 in *Cervus elaphus*.

Eimeria bovis Züblin, 1908 of Ryšavý, 1954 in *Cervus elaphus*.

Eimeria crandallis Honess, 1942 of Ryšavý, 1954 in *Cervus elaphus*.

Eimeria ninae-kohl-yakimovi Yakimoff and Rastegaieva, 1930 of Ryšavý, 1954 in *Cervus elaphus*.

Eimeria parva Kotlan, Moczy and Vajda, 1929 of Ryšavý, 1954 in *Cervus elaphus*.

Description. None.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus elaphus* (European red deer).

Other Hosts. See Remarks.

Location. Oocysts in feces.

Geographic Distribution. Europe (Czechoslovakia).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Ryšavý (1954) reported the above 6 species of *Eimeria* as occurring in *Cervus elaphus* in Czechoslovakia. The natural host of *E. arloingi* is the domestic goat, that of *E. auburnensis* and *E. bovis* is the ox, and that of the other 3 species is the domestic sheep. Since Ryšavý did not describe any of them from the red deer, and since he attempted no cross-transmission experiments, it is impossible to give them names; it is extremely doubtful that they actually belonged to the species to which he assigned them.

Eimeria hegneri Rastegaieff, 1930

Description. Oocysts ovoid, flattened at the small end, 16-18 by 11-14 μ , with a micropyle 3.6 μ in diameter. This form apparently did not sporulate. No further description given.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus canadensis* (wapiti).

Other Hosts. None.

Location. Feces.

Geographic Distribution. Leningrad zoo.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Rastegaieff (1930) described this species from 2 wapiti in the Leningrad zoo. Although the oocysts apparently did not sporulate, she nevertheless assigned them to the genus *Eimeria* and established a new species for them. Whether it is a valid species remains to be determined by future study.

***Eimeria wapiti* Honess, 1955**

(PLATE 8, FIG. 41)

Description. Oocysts ovoid, 32-42 by 24-29 μ with a mean of 38.2 by 26.3 μ . Oocyst wall light yellowish brown, 1.5-2 μ thick, with its outer surface pitted with small craters; number of layers not stated. Micropyle present, about 4 μ in diameter. Sporocysts boat-shaped, pointed at one end and somewhat rounded at the other, 20 by 9.5 μ . Oocyst and sporocyst residua absent.

Sporulation Time. Five to 8 days at room temperature.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Cervus canadensis nelsoni* (elk).

Other Hosts. None.

Location. Feces.

Geographic Distribution. USA (Wyoming)

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

***Eimeria oweni* Alderson, 1951**

Nomen nudum.

Remarks. Alderson (1951) named this species as occurring in the elk (*Cervus canadensis nelsoni*) in Wyoming, but did not describe it. The name is therefore a *nomen nudum*.

***Eimeria zürni* Rivolta, 1878**

Rastegaieff (1930) reported finding this species in 2 wapiti (*Cervus canadensis*) in the Leningrad zoo. The oocysts were spherical, 14 μ in

diameter, without a micropyle. She gave no further description of them, but simply stated that she considered them to be "*Eimeria zürni*."

Honess (1955) reported that "*Eimeria zurnii*" had been found occasionally in the feces of the elk *Cervus canadensis nelsoni* in Wyoming. The oocysts were usually spherical, but a few were subspherical; they were 12-28 μ long and 10-20 μ wide. He said that they were structurally like the oocysts from the cattle, but gave no further information.

This form might possibly be *E. elaphi*, which Jansen and van Haaften (1966) described from *C. elaphus*.

Eimeria sp. Yakimoff, 1935

Eimeria wassilewsky [sic] Rastegaieff of Yakimoff, 1935b (*pro parte*).

Description. Oocysts ovoid, without micropyle, 27 by 19.5-21 μ (apparently only 2 oocysts were measured). Oocyst residuum absent. Sporocysts ovoid. Sporozoites ovoid or piriform.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Pathogenicity. Unknown.

Type Host. *Sika hortulorum* (syns., *Pseudoaxis dybovskyi*, *P. hortulorum*) (Dybovsky's deer).

Other Hosts. None.

Location. Feces.

Geographic Distribution. USSR (Ukraine).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff (1935b) found this form in one out of 4 *S. hortulorum* from Askania Nova, Ukraine.

Remarks. Although Yakimoff (1935b) said that this form was "*Eimeria wassilewsky* Rastegaieff," it is not. It differs from *E. wassilewskyi* in oocyst shape and in lacking the micropyle which Rastegaieff's drawing indicated as present. In addition, it occurs in a different host genus (*Sika*). What it is remains to be determined.

Host Suborder RUMINANTIA

Host Superfamily CERVOIDEA

Host Family CERVIDAE

Host Subfamily ODOCOILEINAE

Host Tribe ODOCOILEINI

***Eimeria mccordocki* Honess, 1941**

(PLATE 10, FIG. 62; PLATE 64, FIG. 286)

Description. Oocysts ellipsoidal, 33-37 by 25-29 μ with a mean of 34.8 by 26.6 μ . Oocyst wall composed of 2 layers, 1.1 μ in total thickness. Outer layer smooth, deep yellowish brown; inner layer not described. Micropyle present, 5-6 μ wide. Oocyst residuum absent. Oocyst polar granule not mentioned. Sporocysts 18-21 by 8-12 μ , oblong, with one end pointed and the other bluntly rounded. Stieda body present. Sporocyst residuum present. (Landram and Honess, 1955).

Sporulation Time. Five to 9 days at room temperature.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Odocoileus h. hemionus* (mule deer).

Other Hosts. *O. virginianus* (white-tailed deer).

Location. Feces.

Geographic Distribution. USA (Pennsylvania, Texas, Wisconsin, Wyoming).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Honess and Winter (1956) found this species in mule deer from a number of localities in Wyoming. Anderson and Samuel (1969) found it in 13% of 372 white-tailed deer in Texas, 12% of 146 in Pennsylvania and 10% of 683 in Wisconsin.

***Eimeria odocoilei* Levine, Ivens and Senger, 1967**

(PLATE 7, FIG. 39; PLATE 64, FIG. 288)

Description. Oocysts smooth, subspherical, without micropyle. Oocysts 26-28 by 22-26 μ with a mean of 26.9 by 23.5 μ . Oocyst wall composed of a single layer about 1.3 μ thick (confirmed by breaking the wall); outer $\frac{2}{3}$ of wall colorless and inner third brownish yellow, giving the illusion of 2 layers. Oocyst polar granule present. Oocyst residuum absent. Sporocysts ovoid, with Stieda body at small end, with sporocyst residuum, 13-15 by 8-10 μ with a mean of 13.6 by 9.1 μ . Sporozoites appearing broadly comma-shaped, lying lengthwise head to tail in sporocysts, with a clear globule at broad end; sporozoites sausage-shaped after release from sporocysts.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Odocoileus h. hemionus* (mule deer).

Other Hosts. *O. virginianus* (white-tailed deer).

Location. Oocysts found in feces.

Geographic Distribution. USA (Pennsylvania, Texas, Washington, Wisconsin).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Anderson and Samuel (1969) found this species in 1 of 372 white-tailed deer in Texas, 1 of 146 in Pennsylvania, and 1% of 683 in Wisconsin.

***Eimeria ivensae* Todd and O'Gara, 1969**

(PLATE 65, FIG. 290)

Description. Oocysts ovoid to slightly piriform, flat on narrow end, 30-37 by 18-22 μ with a mean of 32.5 by 21.0 μ . Oocyst wall rough, about 1.5 μ thick, composed of 2 layers, of which the outer is brown and about $\frac{3}{4}$ of the wall thickness and the inner is light blue. Micropyle 4-5 μ in diameter, at narrow end of oocyst. Oocyst polar granule present. Oocyst residuum absent. Sporocysts elongate ovoid, with or without minute Stieda body, with residuum, 14-18 by 6-9 μ with a mean of 16 by 7 μ . Sporozoites lie lengthwise head to tail in sporocysts, with a clear globule at each end.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Odocoileus h. hemionus* (mule deer).

Other Hosts. None.

Location. Unknown. Oocysts found in colon contents.

Geographic Distribution. USA (Montana).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

***Eimeria virginianus* Anderson and Samuel, 1969**

(PLATE 64, FIG. 287)

Description. Oocysts elongate ovoid to ellipsoidal, 42-55 by 26-42 μ with a mean of 49 by 33 μ , with micropyle 3-6 μ in diameter. Oocyst

wall rough, composed of 2 layers of which the outer is 3 μ thick and yellow brown and the inner is less than 1 μ thick. Oocyst polar body and residuum absent. Sporocysts thin-walled, ellipsoidal, pointed at one end, with a Stieda body and apparently no sporocyst residuum, 19-27 by 8-11 μ with a mean of 24 by 10 μ . Sporozoites banana-shaped, rounded at both ends, lying lengthwise in sporocysts, usually with 4 large clear globules.

Sporulation Time. Nine to 11 days at 22-23 C according to Anderson and Samuel, 1969.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Odocoileus virginianus* (white-tailed deer).

Other Hosts. None.

Location. Unknown. Oocysts found in feces.

Geographic Distribution. USA (Pennsylvania, Wisconsin).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Anderson and Samuel (1969) found this species in 3% of 146 white-tailed deer from Pennsylvania and in 5 of 683 from Wisconsin.

***Eimeria madisonensis* Anderson and Samuel, 1969**

(PLATE 64, FIG. 289)

Description. Oocysts spherical or subspherical, with a smooth, pale yellow wall composed of 2 layers (illustrated as composed of a single layer), without micropyle, without oocyst polar granule or residuum, 14-19 by 13-16 μ with a mean of 16 by 15.5 μ . Sporocysts thin-walled, ellipsoidal, with prominent Stieda body but no sporocyst residuum, 6.5-8.5 by 4-6 μ with a mean of 7.5 by 4.5 μ . Sporozoites elongate, lying lengthwise head to tail in sporocysts, with a small clear globule at the large end.

Sporulation Time. Two to 5 days at 22-23 C according to Anderson and Samuel (1969).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Odocoileus virginianus* (white-tailed deer).

Other Hosts. None.

Location. Unknown.

Geographic Distribution. USA (Iowa, Wisconsin).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Anderson and Samuel (1969) found this species in 3 of 683 white-tailed deer from Iowa and Wisconsin.

Host Suborder RUMINANTIA

Host Superfamily CERVOIDEA

Host Family CERVIDAE

Host Subfamily ODOCOILEINAE

Host Tribe RANGIFERINI

Eimeria (?) *polaris* Yakimoff and Sokoloff, 1935

(PLATE 10, FIG. 64)

Eimeria polaris Yakimoff and Sokoloff, 1935.

Description. Oocysts yellowish, ovoid, ellipsoidal, cylindroid or tapering to both ends with one end flattened. Micropyle present in many oocysts but not seen in all. Oocyst wall described as double contoured but illustrated as a single layer. Oocysts 24-34.5 by 15-21 μ . Yakimoff, Sokoloff and Matschoulsky (1936) stated that a polar granule was present. However, neither they nor Yakimoff and Sokoloff (1935) apparently saw sporulated oocysts.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Rangifer tarandus* (reindeer).

Other Hosts. None.

Location. Feces.

Geographic Distribution. USSR (Bolshaya Zemlya, Murmansk area, Kola Peninsula).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff and Sokoloff (1935) found this species in 13% of 84 reindeer from Bolshaya Zemlya. Yakimoff, Sokoloff and Matschoulsky (1936) found it in 1 of 39 reindeer from the Murmansk area. Yakimoff, Matschoulsky and Spartansky (1937) found it in 2 out of 27 reindeer from the western half of the Kola Peninsula.

Remarks. Since no sporulated oocysts of this species have apparently been seen, it is uncertain whether it is truly an *Eimeria*. Further research is needed to establish its genus.

***Eimeria mayeri* Yakimoff, Sokoloff and Matschoulsky, 1936**

(PLATE 8, FIG. 42)

Eimeria sp. Yakimoff and Sokoloff, 1935.

Description. Oocysts subspherical, seldom spherical, 16-20 by 14-16 μ with a mean of 17 by 15 μ . Micropyle absent. Oocyst wall double contoured, illustrated as composed of a single layer (said in the text to have an indentation at one end but not so illustrated; this might possibly be a micropyle). Oocyst residuum absent. Oocyst polar granule present. Sporocysts elongate ovoid, pointed at both ends, 8-13 by 5.4 μ , without Stieda body or sporocyst residuum. Sporozoites with a clear globule at one end, lying lengthwise in sporocysts.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Rangifer tarandus* (reindeer).

Other Hosts. None.

Location. Feces.

Geographic Distribution. USSR (Bolshaya Zemlya, Murmansk area).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff, Sokoloff and Matschoulsky (1936) found this species in 2 of 39 reindeer from the Murmansk area. Yakimoff and Sokoloff (1935) found it in 1 of 84 reindeer from Bolshaya Zemlya.

***Eimeria muehlensi* Yakimoff, Sokoloff and Matschoulsky, 1936**

(PLATE 8, FIG. 43)

Description. Oocysts ovoid, with one end tapered, with a micropyle at the tapered end. Oocyst wall composed of 2 layers (described as tricontoured), 2.0 μ in total thickness, the outer layer light yellowish and disappearing at the micropylar end, the inner layer darker, almost brown, covering the micropyle. Seven oocysts (all that were seen) were 32-40 by 26-28 μ with a mean of 36 by 27 μ . Oocyst polar granule and oocyst residuum absent. Sporocysts ovoid, 16-20 by 8-10 μ , with a prominent Stieda body and a sporocyst residuum. Sporozoites comma-

shaped, 12-14 by 4-6 μ , illustrated with a clear globule at the large end.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Rangifer tarandus* (reindeer).

Other Hosts. None.

Location. Feces.

Geographic Distribution. USSR (Murmansk area).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff, Sokoloff and Matschoulsky (1936) found this species in one of 39 reindeer from the Murmansk area.

***Eimeria tarandina* Yakimoff, Sokoloff and Matschoulsky, 1936**

(PLATE 8, FIG. 44)

Description. Oocysts yellowish or transparent, subspherical, sometimes spherical, 18-24 by 16-22 μ with a mean of 20 by 18 μ . Micropyle absent. Oocyst wall double contoured, illustrated as composed of a single layer. Oocyst polar granule and residuum absent. Sporocysts elongate ovoid, 12-14 by 6-8 μ , with a broad, blunt, prominent Stieda body. Sporocyst residuum present. Sporozoites illustrated with a clear globule at one end.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Rangifer tarandus* (reindeer).

Other Hosts. None.

Location. Feces.

Geographic Distribution. USSR (Murmansk area, Kola Peninsula).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff, Sokoloff and Matschoulsky (1936) found this species in 3 out of 39 reindeer from the Murmansk area. Yakimoff, Matschoulsky and Spartansky (1937) found it in one out of 27 reindeer from the western half of the Kola Peninsula.

***Eimeria arctica* Yakimoff, Matschoulsky and Spartansky, 1939**

(PLATE 7, FIG. 40)

Description. Oocysts ovoid, 32-38 by 26-30 μ with a mean of 35.5 by 28 μ . Oocyst wall yellowish, double-contoured (illustrated as composed of a single layer), 1.0-1.2 μ thick. Micropyle present at small end. Oocyst residuum and oocyst polar granule absent. Sporocysts ovoid, 12-14 by 7-9 μ , without Stieda body but with sporocyst residuum. Sporozoites comma-shaped.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Rangifer tarandus* (reindeer).

Other Hosts. None.

Location. Feces.

Geographic Distribution. USSR (Kola Peninsula).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff, Matschoulsky and Spartansky (1939) found this species in one out of 7 reindeer on the Kola Reindeer Farm.

Host Suborder RUMINANTIA

Host Superfamily CERVOIDEA

Host Family CERVIDAE

Host Subfamily ODOCOILEINAE

Host Tribe CAPREOLINI

***Eimeria capreoli* Galli-Valerio, 1927**

(PLATE 9, FIG. 53)

Description. According to Galli-Valerio (1927), the oocysts were ovoid, with a slightly flattened end, 24 by 13 μ , with a distinct micropyle. The sporocysts were ovoid, 6 by 3 μ , and the sporozoites piriform and 1.5 by 0.9 μ . According to Pellérdy (1955), the oocysts were ovoid or piriform, with the narrow end flattened, 25-35 by 19-26 μ with a mean of 30 by 21 μ . A micropyle was present at the small end. Oocyst wall smooth, yellowish, quite thick, illustrated as probably composed of 2 layers, of which the outer was pale and the inner a heavy line. Oocyst polar granule and oocyst residuum absent. Sporocysts elongate oval, 13-16 by 6-10 μ , with some residual granules which disappear in

several weeks. Supperer and Kutzer (1961) recorded the same data as Pellérdy.

Sporulation Time. Pellérdy (1955) found that the sporulation time at room temperature in 2% potassium bichromate solution was 4-5 days.

Schizogony and Gametogony. Unknown.

Prepatent Period. Pellérdy (1955) found that the prepatent period was 10 days, and that the largest numbers of oocysts were passed 12-13 days after infection.

Type Host. *Capreolus capreolus* (roe deer).

Location. Oocysts in feces.

Geographic Distribution. Europe (Switzerland, Hungary, Austria).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Despite the differences in dimensions given by Galli-Valerio (1927) and Pellérdy (1955), we believe that these authors were both dealing with the same species.

Pellérdy (1955) was unable to infect a 3-month-old roe deer with sheep or goat coccidia by placing it in the same stall with these animals for 2 months. This finding suggests that roe deer do not have the same species of coccidia as sheep or goats. (Pellérdy's description was based on oocysts from a young roe deer infected with oocysts from other roe deer.)

Eimeria ponderosa Wetzel, 1942

(PLATE 8, FIGS. 45, 46 and 48; PLATE 9, FIG. 55)

Description. According to Wetzel (1942), the oocysts were ovoid, with a drawn out and slightly flattened small end (i.e., piriform), and were 38-45 by 25-29 μ with a mean of 40 by 27 μ (Levi, 1967, said that the oocysts averaged 41 by 28 μ). Oocyst wall yellowish brown, 2.5 μ thick (except somewhat thinner at the small end), with a rough surface, composed of 2 layers, of which the inner one was transparent and scarcely 1 μ thick, and the outer one was brownish, rough and easily detached from the inner one. Micropyle in the outer layer but not in the inner one. Following sporulation, neither an oocyst residuum nor oocyst polar granule was seen. Sporocysts ovoid, 19 by 9.4 μ , with a sporocyst residuum. Stieda body not mentioned, but illustrated as possibly present. Sporozoites elongate, 16 by 6 μ , with one end wider than the other, lying lengthwise head to tail in sporocysts, with a clear

globule near the broad end. Wetzel (1942) found relatively few oocysts at the surface after flotation in saturated salt solution, but greater numbers were present in the sediment. He therefore gave this species the name *ponderosa*. Pellérdy (1955) gave the oocyst dimensions as 38-45 by 25-29 μ with a mean of 39.6 by 27 μ ; the sporocysts were elongate and 19 by 9.4 μ . The other characteristics which he reported were the same as those given by Wetzel (1942). According to Böhm and Supperer (1956), the oocyst wall was composed of 3 layers, of which the inner 2 were thin and the outer one thick, yellowish brown and rough. According to Boch and Lucke (1961), the oocysts averaged 40.4 by 26.4 μ ; they said that oocysts with a thick, rough wall predominated at first, but that after sporulation, and perhaps due to the flotation solution, the outer layer came off so that the oocysts appeared smooth and thin-walled; a similar phenomenon was reported by Wetzel (1942) and Pellérdy (1955).

Sporulation Time. According to Wetzel (1942) the sporulation time in 5% potassium bichromate solution at 20 C was 18 days. According to Pellérdy (1955), sporulation began on the 10th day and ended on the 19th.

Schizogony and Gametogony. Unknown.

Prepatent Period. According to Pellérdy (1955), the prepatent period was 15 days.

Type Host. *Capreolus capreolus* (roe deer).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Germany, Hungary, Yugoslavia, Austria).

Pathogenicity. Pellérdy (1955) found severe hemorrhagic inflammation of the small and large intestines of a roe deer which had died in the Budapest Zoo. Since he found no bacteria which might have caused the condition, and since he found about 1000 oocysts per microscope field in the large intestine, he believed that the coccidia had caused the condition.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Eimeria rotunda Pellérdy, 1955

(PLATE 8, FIG. 51; PLATE 9, FIG. 54)

Description. Oocysts generally spherical, sometimes subspherical. (Boch and Lucke, 1961, found some ovoid forms.) Oocysts 11-14 μ in

diameter according to Pellérdy (1955), or 13-18 by 12-14 μ according to Boch and Lucke (1961). Oocyst wall thin, smooth, colorless, apparently composed of a single layer. Micropyle absent. Oocyst residuum absent. Oocyst polar granule presumably absent. Sporocysts presumably spherical, 6 μ in diameter. Sporocyst residuum composed of several granules.

Sporulation Time. Two to 3 days, according to Pellérdy (1955).

Schizogony and Gametogony. Unknown.

Prepatent Period. Four days, according to Pellérdy (1955).

Type Host. *Capreolus capreolus* (roe deer).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Hungary, Austria, Germany).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. According to Pellérdy (1955), this species was reported mistakenly as *E. zuernii* by Salhoff (1939), Ryšavý (1954) and others.

***Eimeria superba* Pellérdy, 1955**

(PLATE 8, FIG. 49)

Eimeria auburnensis Christensen and Porter, 1939 of Böhm and Supperer, 1956.

Description. Oocysts elongate ovoid, sometimes asymmetrical or distorted, illustrated as subellipsoidal, slightly ovoid. Oocysts 43-50 by 30-34 μ with a mean of 46 by 32 μ according to Pellérdy (1955), 43-50 by 29-34 μ according to Boch and Lucke (1961). Micropyle present. Oocyst wall 3 μ thick, composed of 2 layers of which the outer was dark brown and rough and the inner smooth and clear. The outer layer was easily lost in potassium bichromate solution. Oocyst residuum and oocyst polar granule absent. Sporocysts elongate ovoid, 16-21 by 10-12 μ , with a Stieda body and sporocyst residuum.

Sporulation Time. Ten to 12 days, according to Pellérdy (1955).

Schizogony and Gametogony. Unknown.

Prepatent Period. Eighteen days, according to Pellérdy (1955).

Type Host. *Capreolus capreolus* (roe deer).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Hungary, Austria, Germany).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Pellérdy (1955) remarked that this species resembled *E. auburnensis* from the ox, *E. cervi* from the red deer, and *E. muehlensi* from the reindeer. This is undoubtedly the form that Böhm and Supperer (1956) found in the roe deer in Austria and called *E. auburnensis*.

***Eimeria panda* Supperer and Kutzer, 1961**

(PLATE 8, FIG. 47; PLATE 9, FIGS. 56 and 57)

Description. Oocysts narrowly ovoid, sometimes bean-shaped, flattened at the small end, 31-35 by 14-16 μ (25-34 by 14-20 μ according to Boch and Lucke, 1961). Micropyle present at small end. Oocyst wall smooth, illustrated as composed of a single layer. Oocyst residuum and oocyst polar granule absent. Sporocysts elongate ovoid (described as elongate ellipsoidal but illustrated as elongate ovoid), with a Stieda body at the small end, 13 by 7 μ , with a small sporocyst residuum.

Sporulation Time. Three to 4 days, according to Supperer and Kutzer (1961).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Capreolus capreolus* (roe deer).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Austria, Germany).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

***Eimeria* sp. Boch and Lucke, 1961**

(PLATE 8, FIG. 50)

Description. Oocysts ellipsoidal, 30-40 by 22-25 μ , with a smooth, clear wall illustrated as composed of a single layer. Micropyle indistinct. Oocyst residuum and oocyst polar granule absent. Shape and characteristics of sporocysts not given.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Capreolus capreolus* (roe deer).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Germany).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Boeh and Lucke (1961) thought at first that this resembled a smooth variety of *E. auburnensis*, but examination of *E. auburnensis* from the U.S. revealed that it did not.

***Eimeria* spp. Ryšavý, 1954**

Eimeria arloingi Marotel, 1905 of Ryšavý, 1954 in *Capreolus capreolus*.

Eimeria auburnensis Christensen and Porter, 1939 of Ryšavý, 1954 in *Capreolus capreolus*.

Eimeria bovis Züblin, 1908 of Ryšavý, 1954 in *Capreolus capreolus*.

Eimeria crandallis Honess, 1942 of Ryšavý, 1954 in *Capreolus capreolus*.

Eimeria faurei Moussu and Marotel, 1901 of Ryšavý, 1954 in *Capreolus capreolus*.

Eimeria intricata Spiegl, 1925 of Ryšavý, 1954 in *Capreolus capreolus*.

Eimeria ninae-kohl-yakimovi Yakimoff and Rastegaieva, 1930 of Ryšavý, 1954 in *Capreolus capreolus*.

Eimeria parva Kotlan, Moczy and Vajda, 1929 of Ryšavý, 1954 in *Capreolus capreolus*.

Description. None, except that Ryšavý (1954, 1956) said that the oocysts of "*E. intricata*" in *C. capreolus* were smaller than in the sheep (36-48 by 31-36 μ) and had a smaller micropylar cap which was "völlig undeutlich."

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Capreolus capreolus* (roe deer).

Other Hosts. See Remarks.

Location. Oocysts in feces.

Geographic Distribution. Europe (Czechoslovakia).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Ryšavý (1954) reported the above 8 species of *Eimeria* as occurring in *Capreolus capreolus* in Czechoslovakia. The natural host of *E. arloingi* and *E. ninakohlyakimovae* is the domestic goat, that of *E. auburnensis* and *E. bovis* the ox, and that of the others is the domestic sheep. Since Ryšavý did not describe any of these coccidia from the roe deer, and since he attempted no cross-transmission studies, it is impossible to give them names; it is extremely doubtful that they actually belonged to the species to which he assigned them.

Host Suborder RUMINANTIA

Host Superfamily BOVOIDEA

Host Family ANTILOCAPRIDAE

Eimeria antilocaprae Huizinga, 1942 emend.

(PLATE 9, FIG. 52)

Eimeria antelocaprae Huizinga, 1942.

Description. Oocysts ellipsoidal, broadly ellipsoidal or subspherical, 25-35 by 21-30 μ with a mean of 30.8 by 26.0 μ (28-35 by 24-29 μ with a mean of 31 by 27 μ according to Todd, Hammond and O'Gara, 1967). Micropyle absent. Oocyst wall faint dull yellow-green, about 2.0-2.2 μ thick, composed of 2 layers of which the outer is smooth, light yellow-green or blue and about $\frac{2}{3}$ the total thickness and the inner is brown. Oocyst polar granule present. Oocyst residuum present in 86% of freshly sporulated oocysts, but disintegrating into irregularly shaped granules indistinguishable from polar granules 2-4 weeks after sporulation (Todd, Hammond and O'Gara, 1967). Sporocysts about 16.5 by 9.2 μ (13-17 by 8-11 μ with a mean of 15 by 9 μ according to Todd, Hammond and O'Gara, 1967). Stieda body present. Sporocyst residuum present. Sporozoites with one end broad and the other narrow, lying lengthwise head to tail in sporocysts. Clear globule at each end of sporozoites, with nucleus between them. (Information on the sporocysts and sporozoites was given by Todd, Hammond and O'Gara, 1967.)

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Antilocapra americana* (pronghorn, American antelope).

Other Hosts. None.

Location. Oocysts found in cecal and large intestine contents.

Geographic Distribution. USA (Montana, Wyoming).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Todd, Hammond and O'Gara (1967) found this species in 24% of 48 pronghorns from Wyoming and 40% of 15 from Montana.

Remarks. Huizinga (1942) spelled this name "*antilocaprae*," which was a lapsus for "*antilicaprae*."

***Eimeria* sp. Todd, Hammond and O'Gara, 1967**

Description. Oocysts ovoid, 34-35 by 17-20 μ . Oocyst wall about 2.5 μ thick, composed of 2 layers of which the outer was rough. Micropyle present, 3-4 μ in diameter, surrounded by a collarlike thickening of the outer oocyst wall. Oocyst polar granule absent. Oocyst residuum present. Sporocysts 12-14 by 5-7 μ . Stieda body present. Sporocyst residuum present.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Antilocapra americana* (pronghorn).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. USA (Montana).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Todd, Hammond and O'Gara (1967) found this form in one out of 63 pronghorns from Montana and Wyoming.

Remarks. Todd, Hammond and O'Gara (1967) found only 3 oocysts of this form and were uncertain whether it was actually a new species. |

Host Suborder RUMINANTIA

Host Superfamily BOVOIDEA

Host Family BOVIDAE

Host Subfamily BOVINAE

Host Tribe STREPSICEROTINI

***Eimeria canna* Triffitt, 1924**

(PLATE 9, FIG. 58)

Description. Oocysts ovoid (illustrated as almost ellipsoidal), 23.5-34 by 16.5-20 μ . Micropyle present at one end which was slightly flattened. Oocyst wall described as composed of 3 layers, the outermost very delicate, the middle one greenish and hyaline, about 1 μ thick

except at the ends where it was about $0.5\ \mu$ thick, and the inner one a delicate membrane about $0.5\ \mu$ from the middle layer. Oocyst polar granule and oocyst residuum rarely present. Sporocysts ovoid with a distinct hollow nipplelike projection at one end (Stieda body), 12-16.5 by 5.5-6.5 μ . Sporocyst residuum present. Sporozoites elongate, club-shaped, lying lengthwise head to tail in sporocysts, with a clear globule at the large end and sometimes another one near the small end.

Sporulation Time. According to Triffitt (1924), sporulation took 12 days in feces at room temperature (in England) and 5 days when the temperature was raised to 70 F.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Taurotragus oryx* (syn., *Orias canna*) (eland, canna antelope).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. London Zoo.

Pathogenicity. Unknown.

Cross-Transmission Studies. Triffitt (1924) was unable to transmit this species to the domestic rabbit.

Prevalence. Unknown.

Eimeria truffittae Yakimoff, 1934 emend

(PLATE 10, FIG. 61)

Eimeria truffitt Yakimoff, 1934.

Description. Oocysts illustrated as ellipsoidal, 21-24 by 15-19 μ with a mean of 21.1 by 17.8 μ . Micropyle absent. Oocyst wall illustrated as composed of a single layer, with the inner line heavier than the outer. Oocyst polar granule and oocyst residuum absent. Sporocysts elongate with rounded ends, 9 by 4.5-6 μ . Sporocyst residuum described as not "clearly visible" and illustrated as absent. Sporozoites piriform, with one end rounded and the other pointed.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Taurotragus oryx* (syn., *Orias canna*) (eland, canna antelope).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. USSR (Ukraine, presumably in a zoo).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff (1934) found this species in one out of 5 elands.

Host Suborder RUMINANTIA

Host Superfamily BOVOIDEA

Host Family BOVIDAE

Host Subfamily BOVINAE

Host Tribe BOSELAPHINI

Eimeria yakimovi Rastegaieff, 1929

(PLATE 11, FIG. 67)

Description. Oocysts ovoid, 32-41 by 22-29 μ . Micropyle distinct. Oocyst residuum absent. Oocyst polar granule apparently absent. Sporocysts elongate or ovoid, 14 by 9 μ according to Rastegaieff (1929a), 14-19 by 3.05 [*sic*] μ according to Rastegaieff (1930). Stieda body apparently absent. Sporocyst residuum absent. Sporozoites 12-14 by 4.5 μ , vermicular or slightly piriform, lying head to tail, lengthwise in sporocysts.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Boselaphus tragocamelus* (nilgai).

Other Hosts. None.

Location. Feces.

Geographic Distribution. Leningrad and Netherlands Zoos.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Rastegaieff (1930) described this species from oocysts in the feces of two *B. tragocamelus* in the Leningrad Zoo. Zwart (1959) found it in a nilgai (*Portax pirtus* — apparently a synonym of *B. tragelaphus*) in a Netherlands zoo.

Host Suborder RUMINANTIA

Host Superfamily BOVOIDEA

Host Family BOVIDAE

Host Subfamily BOVINAE

Host Tribe BOVINI

***Eimeria azerbaijdshanaica* Yakimoff, 1933**

Eimeria azerbaijdshanaica Yakimoff, 1933 (*lapsus*).

Description. Oocysts 45 by 22 μ , cylindrical, but with one side somewhat concave and the other somewhat convex. Micropyle absent. No other structural information given.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bubalus bubalis* (water buffalo).

Other Hosts. None known.

Location. Oocysts found in feces.

Geographic Distribution. USSR (Azerbaijdshana).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff (1933a) found this species in 7% of 30 water buffaloes in Azerbaijdshana.

Remarks. Supperer (1952) thought that this species was unlikely to occur in cattle. Pellérdy (1965) considered it a dubious species; he said that it was best not to accept it.

***Eimeria thianethi* Gwéléssiany, 1935**

(PLATE 11, FIG. 68)

Description. Oocysts ovoid, grayish-yellow. Oocyst wall 2 μ thick, composed of 2 layers, the outer one being thin and homogeneous (Patnaik, 1965 said that it was rough) and the inner one thick, with transverse striations. Micropyle distinct in some oocysts. Oocysts 34-49 by 26-34 μ with a mean of 43 by 29 μ . Oocyst residuum and oocyst polar granule not seen. Sporocysts not described by Gwéléssiany (1935, 1937). According to Patnaik (1965) the sporocysts were lemon-shaped, with pointed ends, 22 by 9.5 μ ; sporocyst residuum present; Stieda body not seen.

Sporulation Time. Five days according to Patnaik (1965).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bubalus bubalis* (water buffalo).

Other Hosts. *Bos taurus* (ox), *Bos indicus* (zebu).

Location. Oocysts found in feces.

Geographic Distribution. USSR (Georgia), Asia (India).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Gwéléssiany (1935) found this species in 2% of 125 water buffaloes and 1% of 178 cattle in Georgia, USSR. Patnaik (1965) found it in 1% of 136 water buffaloes in Agra, India.

Remarks. Levine and Ivens (1967) gave the reasons why they consider this a distinct species. Patnaik (1965) thought that *E. khurodensis* was a synonym of *E. thianethi*, but Levine and Ivens (1967) said that it was a synonym of *E. auburnensis*.

Svanbaev (1967a) and Bhatia et al. (1968) considered *E. thianethi* a synonym of *E. bukidnonensis*. However, the striated inner wall of the former's oocysts differentiates it.

***Eimeria gokaki* Rao and Bhatavdekar, 1959**

(PLATE 11, FIG. 70)

Eimeria brasiliensis Torres and Ramos, 1939 of Patnaik, 1965.

[non] *Eimeria brasiliensis* Torres and Ramos, 1939.

Description. Oocysts ovoid, 22-31 by 18-25 μ . Oocyst wall thin, homogeneous, slightly yellowish brown. Micropyle present. Micropylar cap 8 μ wide and 3 μ high. Rao and Bhatavdekar (1959) gave no further structural information on this species. Their photomicrograph shows that the sporocysts are elongate and probably have a sporocyst residuum. Patnaik (1965) said that the sporocysts were 16 by 7 μ and had a sporocyst residuum and a thickened "proximal end."

Sporulation Time. Less than 7 days according to Rao and Bhatavdekar (1959).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bubalus bubalis* (water buffalo).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. India.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown. This species was found by Rao and Bhatavdekar (1959) in a single water buffalo calf at Gokak, Mysore State, India. Patnaik (1965) found it in 2% of 136 water buffaloes in Agra, India.

Remarks. Patnaik (1965) and Bhatia et al. (1968) considered this a synonym of *E. brasiliensis*, but its smaller size distinguishes it, and

we feel that, at least for the present, it should be considered a separate species.

***Eimeria ovoidalis* Ray and Mandal, 1961**

(PLATE 11, FIG. 69)

Eimeria wyomingensis Huizinga and Winger, 1942 of Patnaik, 1965.

[non] *Eimeria wyomingensis* Huizinga and Winger, 1942.

Description. Oocysts ovoid, 32-40 by 20-28 μ with a mean of 35.5 by 24 μ . Oocyst wall pinkish orange. Micropyle present. Micropylar cap absent. Oocyst residuum absent. Sporocysts ovoid, with Stieda body at smaller end, 14-16 by 8-9 μ . Sporocyst residuum present. Sporozoites 8-9 by 4-5 μ .

Sporulation Time. Ray and Mandal (1961) reported that the sporulation time was 90-120 hours at 29 C.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bubalus bubalis* (water buffalo).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Asia (India).

Pathogenicity. Unknown.

Cross-Transmission Studies. Ray and Mandal (1961) reported having transmitted this species experimentally to zebu calves. The oocysts in the zebu calves were 20-39 by 16-24 μ , but when these were given to water buffalo calves, oocysts of the original size were discharged.

Prevalence. Ray and Mandal (1961) found this species in one water buffalo calf in West Bengal. Patnaik (1965) reported it (as *E. wyomingensis*) in 7% of 136 water buffaloes in Agra, India.

Remarks. While this species resembles *E. canadensis*, further study will be needed to determine whether it is a synonym. Patnaik (1965) considered this name a synonym of *E. wyomingensis*, but the presence of a sporocyst residuum and the nature of the oocyst wall make this synonymization unacceptable.

***Eimeria bareillyi* Gill, Chhabra and Lall, 1963**

(PLATE 10, FIGS. 65 and 66; PLATE 49, FIG. 202)

Description. Oocysts typically piriform with bluntly truncate small

end and micropyle 5-6 μ wide at small end. Oocysts 26-35 by 19-25 μ with a mean of 31 by 22 μ (24-31 by 15-21 μ with a mean of 28 by 19 μ according to Bhatia et al. 1968). Oocyst wall smooth, homogeneous, yellowish to darkish brown, about 1 μ thick except at the micropylar end where it is thinner, lined by a membrane. (Two layers 1.3 μ thick according to Bhatia et al., 1968.) A few granules composing a "tenue body"* lie beneath the micropyle in sporulated and unsporulated oocysts according to Bhatia et al. (1968). Oocyst residuum present in a few oocysts as a small, irregular mass consisting of 3-4 globules just below the micropyle. Oocyst polar granule absent. Sporocysts lemon-shaped (i.e., broadly ovoid with one end narrower than the other), with a Stieda body at the smaller end, with a mean of 18 by 8 μ (15-18 by 7-9 μ with a mean of 17 by 7 μ according to Bhatia et al., 1968). Sporocyst residuum present, a distinct spherical mass of 5-9 loosely grouped refractile granules in the center of the sporocysts (becoming scattered and scantier with age). Sporozoites banana-shaped, about 10 by 4 μ , each with a refractile spherical globule about 4 μ in diameter at its large end and sometimes one or 2 smaller globules 1-2 μ in diameter. Nucleus central, discernible with phase contrast microscope.

Sporulation Time. Three to 4 days in water or 2% potassium bichromate solution at 29 C.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bubalus bubalis* (water buffalo).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. India (Bareilly, Izatnagar, Nagla, Uttar Pradesh).

Pathogenicity. Gill, Chhabra and Lall (1963) observed heavy discharges of oocysts without clinical symptoms. They found as many as 1.9 million oocysts per gram of feces in buffalo calves and fewer in adult animals.

Cross-Transmission Studies. None.

Prevalence. Bhatia et al. (1968) found this species in 5% of 305 water buffaloes in Mathura, Uttar Pradesh, India.

Remarks. It is possible that the form reported by Abdussalam and Rauf (1956) from a water buffalo calf in Pakistan may have been this species. They said that the oocysts were typically piriform, 29-33

* "Tenue" means simply "small" in Portuguese; Bhatia et al. got this term from the paper by Torres and Ramos (1939).

by 19-23 μ with a mean of 30 by 21 μ , with a homogeneous pinkish brown wall, without a distinct micropyle but apparently with a narrow opening in some specimens, and with sporocysts 15-16 by 6-8 μ ; the sporulation time was apparently more than 4 days. The infected calf had dirty white offensive diarrhea, emaciation, dullness and congestion of the mucous membranes; it went into a coma and died. They thought that this form resembled *E. bovis* but might be a new species. Yasin and Abdussalam (1958) used the name *E. bubalis* for what was presumably this coccidium. However, they credited it to Abdussalam and Rauf (1956), and we have been unable to find any paper in which these latter authors used the name.

Eimeria ankarensis Sayin, 1969

(PLATE 63, FIGS. 282-283)

Description. Oocysts elongate ovoid, 32-43 by 25-29 μ with a mean of 39 by 26 μ . Oocyst wall yellowish brown, composed of 2 layers 3.0-3.5 μ thick and lined by a membrane. Outer layer thick, rough, inner layer very thick, dark brown. Micropyle 6 μ in diameter at small end, not covered by outer layer of wall. Oocyst polar granule and oocyst residuum absent. Sporocysts elongate, almost ellipsoidal, 18-23 by 8-10 μ with a mean of 21 by 9 μ , with Stieda body and sporocyst residuum. Sporozoites elongate, rather comma-shaped, lying lengthwise head to tail in sporocysts, with two refractile globules each.

Sporulation Time. Three to 4 days at room temperature according to Sayin (1969).

Prepatent Period. Unknown.

Type Host. *Bubalus bubalis* (water buffalo).

Other Hosts. None.

Location. Unknown. Oocysts found in feces.

Geographic Distribution. Turkey.

Pathogenicity. Unknown.

Cross-Transmission Studies. Sayin (1969) was unable to transmit this species to the ox by feeding 3 week-old calves 50 sporulated oocysts each.

Prevalence. Sayin (1969) found this species in 10% of 124 water buffaloes in Turkey.

Remarks. Sayin (1969) said that *E. ankarensis* might be confused with *E. thianethi*, *E. bukidnonensis*, *E. wyomingensis* and *E. pellita*, but differentiated it from them. It might also be confused with *E.*

auburnensis, but differs in the character of its wall and micropyle; in addition, Sayin recognized *E. auburnensis* and distinguished between the two forms.

Eimeria zuernii (Rivolta, 1878) Martin, 1909

(PLATE 11, FIGS. 71-76; PLATE 62, FIG. 280)

Cytospermium zuernii Rivolta, 1878.

Eimeria bovis (Züblin, 1908) Fiebiger, 1912 (*pro parte*).

Eimeria canadensis Bruce, 1921 (*pro parte*).

Eimeria zuerni (Rivolta, 1878) Martin, 1909 of Pellérdy, 1965.

Description. Oocysts subspherical, subovoid, ovoid or sometimes ellipsoidal. Oocyst wall smooth, colorless, composed of a single layer about $0.7\ \mu$ thick (except a little thinner at the small end if there is one) (oocyst wall in water buffalo composed of 2 layers $1.5\ \mu$ thick according to Bhatia et al., 1968). Micropyle absent. Oocysts 12-29 by 10-21 μ with means of 17-20 by 14-17 μ . Oocyst residuum absent. One or more oocyst polar granules may or may not be present; if present, sometimes shattered. Sporocysts elongate ovoid, with a tiny Stieda body, 7-13 by 4-7 μ with a mean of 9-11 by 5 μ . Sporocyst residuum present or absent; when present, composed of scattered or rather small granules or occasionally a small, compact mass. Sporozoites elongate, head to tail in sporocysts, with a clear globule at the large end and a nucleus sometimes visible near the center. Free sporozoites 8-10 by 2-3 μ with a mean of 9 by 2 μ (Nyberg and Hammond, 1965) (see figure by Christensen, 1941).

Sporulation Time. According to Marquardt, Senger and Seghetti (1960), complete sporulation occurs in 9-10 days at 12 C, 6 days at 15 C, 3 days at 20 C, 40 hours at 25 C and 23-24 hours at 30-32.5 C; a few oocysts may sporulate at temperatures as low as 8 C in several months, but sporulation is not normal above 32 C. According to Lee and Armour (1959), complete sporulation occurs in 48-72 hours at 27 C; Svanbaev (1967a) found that it was 2-3 days at 25-28 C.

Schizogony and Gametogony. Davis and Bowman (1957) described the endogenous stages. Schizonts are found 2-19 days after experimental infection in the epithelial cells of the upper, middle and lower small intestine, cecum and colon. When mature they are about 10 by 13 μ and contain 24-36 merozoites. They lie distal to the host cell nucleus. Merozoites are first seen 7 days after infection. They are about 5 by 12 μ , have a nucleus near the tapering end and contain 2 refractile globules. Davis and Bowman did not determine the number of asexual

generations, but believed that there is more than one. The mature schizonts late in the cycle are slightly larger than the early ones.

Macrogametes are first seen 12 days after infection. They occur in the epithelial cells of the glands and are to a lesser extent on the surface of the lower small intestine, cecum, colon and rectum, and rarely in the upper small intestine. They are about 11 by 14 μ and contain one or 2 rows of plastic granules. Microgametocytes are first seen 15 days after infection in the same location as the macrogametes. They are about 10 by 14 μ when mature. Immature oocysts are first seen 12 days after infection. According to Svanbaev (1967a), the patent period is about 11 days.

Prepatent Period. About 17 days (Pellérdy, 1965) or 15 days (Svanbaev, 1967a).

Type Host. *Bos taurus* (ox).

Other Hosts. *Bos indicus* (zebu), *Bubalus bubalis* (water buffalo, carabao). Other authors have reported this species from the wisent, white-tailed deer, roe deer and elk, but without descriptions; they were probably dealing with another species.

Location. Schizonts and merozoites in epithelial cells of small intestine, cecum and colon. Gamonts in epithelial cells of lower small intestine, cecum, colon and rectum, rarely in upper small intestine.

Geographic Distribution. Worldwide.

Pathogenicity. *E. zuernii* is the most pathogenic coccidium of cattle. In acute infections it causes a bloody diarrhea of calves. At first the feces are streaked with blood. The diarrhea becomes more severe; bloody fluid, clots of blood and liquid feces are passed; and straining and coughing may cause this mixture to spurt out as much as 2-3 m. The animal's rear quarters may look as though they had been smeared with red paint. Anemia, weakness and emaciation accompany the dysentery, and secondary infections, especially pneumonia, are common. This acute phase may continue for 3 or 4 days. If the calf does not die in 7-10 days, it will probably recover.

E. zuernii may also be associated with a more chronic type of disease. Diarrhea is present, but there may be little or no blood in the feces. The animals are emaciated, dehydrated, weak and listless, with rough hair coats, drooping ears and sunken eyes.

The lesions of coccidiosis were described by Boughton (1945) and Davis and Bowman (1952) among others. A generalized catarrhal enteritis involving both the small and large intestines is present. The lower small intestine, cecum and colon may be filled with semifluid, bloody material. Large or small areas of intestinal mucosa may be eroded and destroyed, and the mucous membrane may be thickened.

with irregular whitish ridges in the large intestine or smooth, dull gray areas in the small intestine or cecum. Diffuse hemorrhages are present in the intestines in acute cases, and petechial hemorrhages in mild ones.

Cross-Transmission Studies. Sayin (1969) claimed to have infected 3-week-old calves (*Bos taurus*) with *E. zuernii* from the water buffalo.

Prevalence. Boughton (1945) found this species in 42% of 2,492 bovine fecal samples in the southeastern United States; Hasche and Todd (1959a) in 26% of 355 cattle in Wisconsin; Szanto, Mohan and Levine (1964) in 37% of 795 beef calves in Illinois; Nyberg, Helfer and Knapp (1967) in 23% of 86 cattle in Oregon; Jacobson and Worley (1969) in 6% of 486 calves and 5% of 479 adult cattle in Montana; Torres and Ramos (1939) in 38% of 146 cattle in Brazil; Ruiz (1959) in 1% of 100 adult cattle in Costa Rica. Ruiz and Ortiz (1961) in 2% of 100 calves in Costa Rica; Baleoni (1963) in 25% of 100 adult cattle in Guatemala; Supperer (1952) in 11% of 130 cattle in Austria; Patyk (1965) in 16% of 341 calves in Poland; Chroust (1964) in 83% of 77 cattle in Czechoslovakia; Joyner et al. (1966) in 64% of 110 cattle in England; Yakimoff, Gousseff and Rastegaieff (1932a) in 13% of 126 oxen in Uzbekistan; Marchenko (1937) in 20% of 137 cattle in North Caucasus; Yakimoff (1933a) in 18% of 41 oxen, 6% of 17 zebus and 37% of 30 water buffaloes in Azerbaidzhan; Sayin (1969) in 49% of 124 water buffaloes in Turkey; Vassiliadés (1969) in 38% of the cattle he examined in Senegal; Tubangui (1931) in 11% of 28 zebus and 9% of 11 carabaos in the Philippines; Patnaik (1965) in 36% of 136 water buffaloes at Agra, India; and Watanabe and Iwata (1956) in 3% of 454 cattle in Japan. Svanbaev (1967a) found it in a calf as early as 15 days after birth; he found it in 30% of 781 cattle 2 months to more than a year old in Kazakhstan. Bhatia et al. (1968) found it in 16% of 305 water buffaloes in Mathura, Uttar Pradesh, India.

Remarks. The proper way to spell this name has been discussed by Levine and Ivens (1967).

Eimeria bovis (Züblin, 1908) Fiebiger, 1912

(PLATE 12, FIGS. 77-81; PLATE 13, FIGS. 82-92; PLATE 14, FIGS. 93-96; PLATE 15, FIGS. 97-102; PLATE 16, FIGS. 103-106; PLATE 17, FIGS. 107-108; PLATE 18, FIGS. 109-110; PLATE 19, FIGS. 111-112; PLATE 20, FIG. 113; PLATE 21, FIG. 114; PLATE 22, FIG. 115; PLATE 23, FIGS. 116-117; PLATE 24, FIG. 118; PLATE 25, FIG. 119; PLATE 26, FIG. 120; PLATE 27, FIG. 121; PLATE 28, FIG. 122; PLATE 29, FIGS. 123-126; PLATE 62, FIG. 276)

Coccidium bovis Züblin, 1908.

Eimeria canadensis Bruce, 1921 (*pro parte*).

Eimeria smithi Yakimoff and Galouzo, 1927.

Eimeria (Globidium) bovis (Züblin, 1908) Reichenow, 1953.

Eimeria aareyi Rao and Bhatavdekar, 1959.

? *Globidium fusiformis* Hassan, 1935.

Description. Oocysts ovoid (described by Christensen, 1941, as typically stoutly ovoid and somewhat blunted across the narrow end, but varying considerably in shape, especially in heavy infections; subellipsoidal, asymmetrical and elongated, tapering oocysts also occur), 23-34 by 17-23 μ with a mean of about 27-29 by 20-21 μ (oocysts in water buffalo 23-43 by 15-26 μ with a mean of 28 by 21 μ according to Bhatia et al., 1968). Oocyst wall smooth (rarely roughened), composed of 2 layers, the outer one colorless and about 1.3 μ thick and the inner one brownish yellow and about 0.4 μ thick (Levine and Ivens, 1967). Micropyle present at small end, inconspicuous. Oocyst polar granule absent. Oocyst residuum absent. Sporocysts elongate ovoid, 13-18 by 5-8 μ with a mean of 15-16 by 7 μ (10-14 by 7-9 μ with a mean of 12 by 8 μ according to Svanbaev, 1967a). Stieda body present, inconspicuous. Sporocyst residuum present. Sporozoites elongate, with one end smaller than the other, lying lengthwise head to tail in sporocysts, usually with one pale globule at each end and often with the nucleus visible near the center. (See figures by Hammond, 1964 and Nyberg and Hammond, 1965).

Sporulation Time. Two to 3 days in water or 2.5% potassium bichromate solution at room temperature.

Schizogony and Gametogony. There are 2 asexual and 1 sexual endogenous stages in the life cycle of *E. bovis*. Hammond et al. (1946) described the first asexual stage in detail. The sporozoites invade the endothelial cells of the lacteals in the villi of the posterior half of the small intestine. These cells become detached from the lacteal lining and lie free and greatly swollen in the lumen of the lacteals. The schizonts are first found 5 days after infection. They grow to giant size, becoming mature 14-18 days after infection. A few may still be found as long as 30 days after inoculation, but most of these are degenerate. The mature schizonts are 207-435 by 134-267 μ with a mean of 281 by 303 μ and contain 55,000-170,000 (mean, 120,000) merozoites. They are easily visible to the naked eye as whitish balls, and their presence was first pointed out by Boughton (1942) as a macroscopic lesion which could be used in diagnosing coccidiosis. Sheffield and Hammond (1966) found that the cyst (host cell) has microvilli on its outer surface.

The first generation merozoites have been studied in detail by Hammond and Ernst (1964) and Hammond, Ernst and Goldman (1965) after staining by conventional methods. Living merozoites are 11-16 by 1-2 μ with a mean of 13.5 by 1.4 μ . They move by flexing or gliding. In protargol preparations they have a cap-like covering with a terminal pore at the anterior end and a median rodlike structure extending back into the body. They also have prominent granules in the posterior $\frac{2}{3}$ of the body, with one characteristically at the posterior end; similar granules have not been seen in the merozoites of other species of *Eimeria*. The nucleus is in the posterior third of the body. Its chromatin is arranged in about 3-5 coarse clumps around the periphery of the nucleus. There are numerous small glycogen granules in the posterior $\frac{2}{3}$ of the body, but no sudanophilic lipids. The merozoites have a strongly argyrophilic anterior ring, long fibrils and a rodlike structure extending posteriorly from the region of the ring, and a strongly argyrophilic posterior granule.

Sheffield and Hammond (1966) studied the fine structure of the first generation merozoites. Approximately 22 subpellicular fibrils extend back from the polar ring. Within the polar ring is a conoid consisting of one or more fibrils wound in a tight helix. Two rhoptries (a term introduced by S  naud, 1964, for the paired organelles) extend backward through the conoid from the anterior end; each is club-shaped, with a narrow neck in the conoid region and a wider posterior part. A median rod parallels the necks of the rhoptries. Numerous ovoid glycogen bodies about 0.4 by 0.2 μ are concentrated in the central third of the merozoite. The region between them and the conoid is tightly packed with many tortuous structures with indistinct borders (i.e., micronemes, a term introduced by Jacobs, 1967). Scattered among them are numerous ribosomes and one or 2 mitochondria. There may also be a dense, membrane-enclosed body, possibly a lysosome, near the mitochondria. The Golgi apparatus lies next to the flattened anterior end of the nucleus. There may be a micropore at the level of the Golgi apparatus. There are several cisternae of rough-surfaced endoplasmic reticulum anterior and posterior to the nucleus.

Sheffield and Hammond (1967) studied the fine structure of the development of the first generation merozoites. At first, the schizont cytoplasm is subdivided into many lobes or spheroidal blastophores. Their peripheries are lined by many nuclei resulting from repeated divisions. A complex of structures which later comprise the merozoite anterior end is then formed in the cytoplasm of each future merozoite. A thickened layer forms under the plasma membrane; it eventually becomes the inner membrane of the merozoite. There is a central open-

ing in this layer, and adjacent to it lies a conoid. Subpellicular fibrils radiate from the opening; they are closely applied to the inner membrane. The blastophore membrane is then elevated into a cone-shaped projection which later elongates into a finger-like bud, which is the developing merozoite. This bud contains the primordia of the rhoptries, a nucleus, Golgi apparatus near the nucleus, and other cytoplasmic structures derived from the blastophore. As the merozoite grows further, the outer and inner membranes are extended posteriorly, and the membranes are folded into the blastophore. Later the merozoites are completely formed but are still attached to the blastophore by their posterior ends. This attachment is then broken, and free merozoites and residual bodies are produced.

It was not realized until the work of Hammond, Andersen and Miner (1963) that there is a second asexual generation in *E. bovis*. It occurs in the epithelial cells of the cecum and colon. The mature schizonts average 9 by 10 μ in tissue sections and contain 30-36 merozoites averaging 3.5 by 1.2 μ . Living second generation merozoites are 6-7 μ long with a mean of 6.2 μ .

The sexual stages were studied in detail by Hammond et al. (1946). They generally occur only in the cecum and colon, but in heavy infections may be found in the terminal 1-1.3 m of the small intestine. They are found in the epithelial cells of the intestinal glands. The cells at the base of the glands are invaded first, and later the rest of the gland becomes involved. The first sexual stages appear 17 days after inoculation. The macrogametes contain plastic granules in their cytoplasm, there being one layer of small granules near the surface and a less distinct layer of larger granules beneath it. Hammond et al. (1946) did not see fertilization, but they saw 2 stages in the union of nuclei before formation of the oocyst wall.

Schlotysek, Hammond and Ernst (1966) described the fine structure of the macrogametes. They contain numerous spheroidal to ellipsoidal or ovoid glycogen inclusions 0.3-1.3 μ in diameter, lipid bodies, broadly ellipsoidal dark bodies close to the cell membrane and 0.4-1.6 μ long, and wall-forming bodies about 1.8 μ long. These last occur singly or in groups in vacuoles. Typical endoplasmic reticulum is well developed in young macrogametes but not present in any appreciable amount in mature ones. The cell boundary consists of 2 membranes, the inner one considerably thicker than the outer. There are numerous fine invaginations or micropores along the entire periphery of the macrogametes; they are about 500 A in diameter and 1000 A deep, normally appearing as blind pouches but sometimes opening into vacuoles. The nucleus has a relatively large nucleolus, with prominent

granules in the karyoplasm. The nuclear membrane is double, with numerous pores.

Hammond, Scholtyseck and Miner (1967) described the fine structure of the microgametocytes. In the early microgametocytes there is widely distributed endoplasmic reticulum, with canals containing electron-dense material, a number of thick-walled vesicles, glycogen granules, and many mitochondria. At the time the microgametes are formed the microgametocytes are 12-18 μ in diameter. The parasitophorous vacuole is narrow, and the microgamont has many microvilli along its free outer surface. These protrusions interdigitate with processes from the host cell cytoplasm; each of the latter processes contains a mitochondrion. Micropores about 1100 A wide and 1100 A deep are occasionally present on the microgamont surface.

Hammond, Ernst and Chobotar (1967) and Hammond, Chobotar and Ernst (1968) described the sporozoites of *E. bovis*. They are 14-17 by 3-4 μ with a mean of 15.6 by 3.3 μ and move by gliding and flexion. They have a relatively large refractile body at the posterior end and one or more smaller refractile bodies anterior to the nucleus. The nucleus is vesicular near the center of the body and has a somewhat eccentric nucleolus and peripheral chromatin. There is a nipple-like projection at the anterior end, some indication of peripheral fibrils and occasionally median rodlike bodies interpreted as rhoptries. There are numerous glycogen granules, mostly in the middle of the sporozoites.

According to Walton (1959), the haploid number of chromosomes in *E. bovis* is 2.

Prepatent Period. Oocysts appear 16-21 days after experimental infection (Hammond, Davis and Bowman, 1944), and most often 18-20 days after infection (Hammond et al., 1946). Large numbers are discharged for 5-7 days, and smaller numbers for 2-3 weeks. In 28 calves studied by Senger et al. (1959), oocysts were discharged for 7-15 days with a mean of 11.5 days. Svanbaev (1967a) found that the prepatent period was 17-18 days and the patent period no more than 10 days.

Patnaik and Pande (1965) and Bhatia and Pande (1967b) described the endogenous stages of a coccidium that they tentatively identified as *E. bovis* in the small intestine of the water buffalo. However, they were dealing with mixed infections, and it is uncertain that this is the species that they actually saw. Pande et al. (1968) described several endogenous stages in the water buffalo intestine but did not attempt to assign them to species.

Type Host. *Bos taurus* (ox).

Other Hosts. *Bos indicus* (zebu). In addition, Tubangui (1931) and Yakimoff (1933a) reported this species from the carabao and

water buffalo (both *Bubalus bubalis*), Patnaik (1965) and Bhatia et al. (1968) from the water buffalo, and Yakimoff (1935b) in the wisent or European bison *Bison bonasus* and the banteng *Bibos banteng*.

Location. The first stage schizonts are in the endothelial cells of the lacteals in the villi of the posterior half of the small intestine. The second generation schizonts are in the epithelial cells of the cecum and colon. The gamonts are generally in the epithelial cells of the glands of the cecum and colon, but may extend up into the terminal 1-1.3 m of the small intestine in heavy infections.

Geographic Distribution. Worldwide.

Pathogenicity. *E. bovis* is one of the 2 most pathogenic of the bovine coccidia. Hammond, Davis and Bowman (1944) studied its effects in experimentally infected calves. An infective dose of 125,000 oocysts or more was generally needed to cause marked signs. These appeared about 18 days after infection, and consisted of diarrhea and/or dysentery, tenesmus, and temperatures as high as 106.6 F. One of 4 calves given 125,000 oocysts became moribund due to coccidiosis, while individual calves given 250,000-1 million oocysts all died or became moribund 24-27 days after infection.

The most severe pathologic changes occur in the cecum, colon and terminal 0.3 m of the ileum. They are due to the gamonts. At first the mucosa is congested, edematous and thickened, with petechiae or diffuse hemorrhages. Its lumen may contain a large amount of blood. Later, the mucosa is destroyed and sloughed, and a patchy or continuous membrane forms over its surface. The submucosa may also be destroyed. If the animal survives, both mucosa and submucosa are later replaced.

Senger et al. (1959) found that infection of calves with *E. bovis* produced partial immunity against subsequent exposure.

Cross-Transmission Studies. Wilson (1931) was unable to infect pigs or goats with *E. bovis* from the ox. Sayin (1969) claimed to have infected 3 week-old calves (*Bos taurus*) with *E. bovis* from the water buffalo.

Prevalence. This is one of the commonest coccidia of cattle. Boughton (1945) found it in 41% of 2,492 bovine fecal samples in southeastern U.S. Hasche and Todd (1959a) found it in 41% of 355 cattle in Wisconsin; Szanto, Mohan and Levine (1964) in 52% of 795 beef calves from 35 farms in Illinois; Nyberg, Helfer and Knapp (1967) in 62% of 86 cattle in Oregon; and Jacobson and Worley (1969) in 61% of 486 calves and 30% of 479 adult cattle in Montana. Fitzgerald (1962) reported that it was the most prevalent species in a

large herd of beef cattle in Utah. Supperer (1952) found it in 66% of 130 cattle in Austria; Joyner et al. (1966) in 75% of 110 bovine fecal samples in England; Chroust (1964) in 69% of 184 calves in Czechoslovakia; Patyk (1965) in 23% of 341 calves in Poland; Torres and Ramos (1939) in 49% of 146 cattle in Brazil; Balconi (1963) in 41% of 100 adult slaughter cattle in Guatemala; Ruiz (1959) in 7% of 100 adult cattle in the San Jose, Costa Rica abattoir; Ruiz and Ortiz (1961) in 31% of 100 calves in Costa Rica; Vassiliades (1969) in 21% of the cattle he examined in Senegal; Watanabe and Iwata (1956) in 4% of 454 healthy cattle in Japan; Yakimoff, Gousseff and Rastegaieff (1932a) in 40% of 126 cattle in Uzbekistan; Yakimoff (1933a) in 47% of 17 zebus, 39% of 44 cattle and 23% of 30 water buffaloes in Azerbaidzhan; Marchenko (1937) in 54% of 137 cattle in the North Caucasus, and Patnaik (1965) in 52% of 136 water buffaloes at Agra, India. Rao and Hiregaudar (1954a) said that it is common in Bombay State, India. Svanbaev (1967a) found it in a calf as early as 20 days after birth; he found it in 26% of 781 cattle 2 months to more than a year old in Kazakhstan. Bhatia et al. (1968) found it in 31% of 305 water buffaloes in Mathura, Uttar Pradesh, India, and Sayin (1969) in 34% of 124 water buffaloes in Turkey.

Cultivation. Fayer and Hammond (1967) inoculated *E. bovis* into embryonic bovine kidney, spleen, intestine, testis and thymus cells. The sporozoites developed only in primary kidney and intestinal cell cultures and in secondary cultures of all these tissues. Schizonts containing merozoites developed only in the kidney, spleen and thymus cells. Fayer and Hammond (1967) added ovine embryonic kidney cells to the list of host cells for this species.

Hammond and Fayer (1967, 1968) cultivated *E. bovis* in monolayer cell line cultures of bovine kidney, bovine trachea, human intestine and mouse fibroblasts (L cells). They obtained mature first generation schizonts in all tissue cultures except the mouse fibroblasts; in these, the sporozoites entered the cells but did not develop beyond a trinucleate stage. Development was especially fast in the bovine trachea cultures; mature schizonts were first seen 8 days after inoculation, and some reached 292 by 118 μ 18 days after inoculation; an early second generation schizont was present 18-19 days after inoculation. The schizonts developed more slowly in bovine kidney cells than in bovine trachea cells; the first mature schizonts were seen only after 14 days, and the largest one, seen 21 days after inoculation, was 55 by 38 μ . Relatively few schizonts developed in the human intestinal cells, but their rate of development was about the same as in bovine kidney

cells. The largest mature schizont, seen 13 days after inoculation, was 109 by 55 μ .

Remarks. Hassan (1935) described the sporozoites and schizonts of an organism which he named *Globidium fusiformis* from 5 zebras with dysentery and rinderpest in India. The schizonts were found in the abomasum, duodenum and ileum; they often occurred anterior to the ileocecal valve, but were not found in the large intestine. They were whitish and measured 0.4-1.0 by 0.8 mm. The merozoites were 13 by 2.0-2.5 μ , elongate, spindle-shaped, slightly curved, with one end bluntly rounded and the other finely pointed. This form may possibly be *E. bovis*. However, the fact that schizonts were found in the abomasum as well as in the small intestine made Hammond et al. (1946) hesitate to assign it to this species, since they never found schizonts of *E. bovis* in the abomasum.

Abdussalam and Rauf (1956) described acute primary coccidiosis in a buffalo (*Bubalus bubalis*) calf in Pakistan with diarrhea, emaciation, dullness, congestion of the visible mucous membranes, coma, and death. The unsporulated oocysts in the feces were 29-33 by 19-23 μ with a mean of 30 by 21 μ , pinkish brown, typically piriform with the narrow end drawn out, without a distinct micropyle. At 28-30 C they began to sporulate in 4 days and continued up to 8 days; the sporocysts were 15-16 by 6-8 μ . They thought that this form resembled *E. bovis* but that it might be a new species. It is possible that it was *E. bareillyi* (see below).

Rao and Bhatavdekar (1959) described a new species of *Eimeria*, *E. aareyi*, in zebras at the Aarey Milk Colony, Bombay State, India. Its oocysts were ovoid, 21-40 by 14-20 μ with a mean of 29 by 20 μ . Its oocyst wall was thin and homogeneous and its micropyle a sharp, dark line continuous with the oocyst wall but thinner and larger, appearing like a lid and about 7.2 μ wide. These authors gave no further structural information except for 2 photomicrographs which revealed little except that the sporocysts were elongate as in most other bovine coccidia. This species resembles *E. bovis*, and Patnaik (1965) considered it a synonym thereof. It is possible that it is a valid species, but in the absence of more information, Patnaik's view seems proper.

Eimeria canadensis Bruce, 1921

(PLATE 30, FIGS. 129-131; PLATE 62, FIG. 275)

Eimeria zurnabadensis Yakimoff, 1931.

Description. Oocysts slightly ovoid or ellipsoidal, usually with a smooth wall but sometimes with a roughened wall. Oocyst wall composed of 2 layers, the outer one colorless to yellowish, about $0.5\ \mu$ thick (but thicker over the micropyle), and the inner one clear, yellow and $1.3\ \mu$ thick (except somewhat thinner over the micropyle). (Levine and Ivens, 1967, found that, while the outer layer looked light and the inner one dark in intact oocysts, the outer layer looked dark and the inner one light in a crushed oocyst.) Oocyst wall at the micropylar end gives the appearance of being almost detached at some focal levels. Oocyst wall lined by a thin membrane. Micropyle at small end of oocyst, inconspicuous, but somewhat collapsed after standing in Sheather's sugar solution. Oocysts 28-38 by 20-29 μ with a mean of 33 by 23-24 μ (oocysts in the water buffalo 25-37 by 18-28 μ with a mean of 31 by 22 μ according to Bhatia et al., 1968). Oocyst residuum and single polar granule generally absent, but a number of splintered polar granules present in some oocysts, and a small amount of amorphous material present at micropylar end of others; Levine and Ivens (1967) saw a single polar granule in one oocyst. Sporocysts elongate ovoid, with one end somewhat broader than the other, 15-22 by 6-9 μ with a mean of 18 by 8 μ (sporocysts in water buffalo 13-17 by 7-8 μ with a mean of 16 by 7.5 μ according to Bhatia et al., 1968). Stieda body present, but merely an inconspicuous thickening of the wall of the small end of the sporocyst. Sporocyst residuum composed of a small number of scattered granules in some sporocysts, a larger number of granules in others, and a compact ball in still others. Sporozoites elongate, lying lengthwise head to tail in sporocysts. Sporozoites with 2-3 clear globules each.

Sporulation Time. Christensen (1941) found that the sporulation time was 3-4 days in tap water, presumably at room temperature; Lee and Armour (1959) found that it was 3-5 days at 27 C.

Schizogony and Gametogony. Unknown.

Patnaik and Pande (1965) described the endogenous stages of a coccidium that they tentatively identified as *E. canadensis* in the water buffalo. However, they were dealing with mixed infections, and it is uncertain that this is the species that they actually saw.

Prepatent Period. Unknown.

Type Host. *Bos taurus* (ox).

Other Hosts. *Bos indicus* (zebu). In addition, Yakimoff (1935a) reported this species from the wisent or European bison *Bison bonasus* and the banteng *Bibos banteng*, and Patnaik (1965) and Sayin (1969) from the water buffalo *Bubalus bubalis*.

Location. Oocysts found in feces.

Geographic Distribution. North America (British Columbia, Alabama, Illinois, Utah, Wisconsin), Central America (Guatemala), Europe (England, East Germany), Africa (Nigeria), Asia (Turkey, India), USSR (Azerbaijan).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Hasche and Todd (1959a) found this species in 35% of 355 cattle in Wisconsin; Szanto, Mohan and Levine (1964) in 35% of 795 beef calves in Illinois; Jacobson and Worley (1969) in 5% of 486 calves and 3% of 479 adult cattle in Montana; Balconi (1963) in 39% of 100 adult cattle in Guatemala; and Joyner et al. (1966) in 13% of 110 cattle in England. Bhatia et al. (1968) found it in 9% of 305 water buffaloes in Mathura, Uttar Pradesh, India; and Sayin (1969) in 20% of 134 water buffaloes in Turkey.

Remarks. Patnaik (1965) considered that *E. bombayensis* was a synonym of *E. canadensis*, but we prefer to list the former as a separate species (see below), at least for the present.

Eimeria ellipsoidalis Becker and Frye, 1929

(PLATE 30, FIGS. 132-134; PLATE 31, FIGS. 135-137; PLATE 62, FIG. 277)

Description. Oocysts ellipsoidal to very slightly ovoid. Oocyst wall smooth, colorless, composed of a single layer (2 layers according to Nyberg and Hammond, 1965 and Bhatia et al., 1968) about $0.8\ \mu$ thick, sometimes apparently lined by a membrane which is often wrinkled at the small end. Micropyle absent, but wall slightly thinner at one end than the other; this is the small end if there is one. Oocysts measured by various authors varied from 12-32 by 10-29 μ ; those seen by Becker and Frye (1929) were 20-26 by 13-17 μ with a mean of 23 by 16 μ ; those seen by Christensen (1941) were 12-27 by 10-18 μ with a mean of 17 by 13 μ ; those seen by Nyberg and Hammond (1965) were 18-26 by 13-18 μ with a mean of 21 by 15 μ ; those seen by Levine and Ivens (1967) were 20-25 by 14-20 μ with a mean of 23 by 16 μ . Oocyst residuum absent. Oocyst polar granule ordinarily absent, occasionally represented by some small shattered granules. Sporocysts elongate ovoid with almost flat sides, and with an inconspicuous, small, flat Stieda body or none at small end. Sporocysts 11-16 by 5-6 μ with a mean of 13-14 by 5 μ (Nyberg and Hammond, 1965; Levine and Ivens, 1967). Sporocyst residuum present, composed of compact or scattered granules. Sporozoites elongate, lying head to tail in sporocysts, with a clear globule at the large end and another near the middle.

Sporozoites larger at one end than the other, 11-14 by 2-3 μ with a mean of 13 by 3 μ at the large end and 13 by 2 μ at the small end (Nyberg and Hammond, 1965).

Sporulation Time. Three days according to Gräfner and Weichelt (1966).

Schizogony and Gametogony. Boughton (1945) said that the endogenous stages were in the epithelial cells of the small intestine mucosa. Hammond, Sayin and Miner (1962, 1963) found merozoites in scrapings from the middle of the small intestine of a calf killed 11 days after inoculation. The mature schizonts were 9-16 by 7.5-15 μ with a mean of 11 by 9 μ and contained 24-36 merozoites 8-11 μ long and 1-2 μ wide, usually lying parallel to each other. They found gamonts and oocysts in the posterior $\frac{1}{2}$ or $\frac{2}{3}$ of the small intestine, the greatest concentration being in the lower ileum. They found immature gamonts 8 days after inoculation and mature ones 10 days after inoculation in epithelial cells near the bottom of the crypts. They were generally distal to the host cell nucleus. They found oocysts, mature macrogametes, microgamonts and microgametes in similar locations in a calf killed 14 days after inoculation. Mature microgamonts were 12-16.5 by 11-16.5 μ with a mean of 15 by 13 μ . The microgametes were 2-3 μ long. Oocysts were discharged continuously for 4-10 and then intermittently for 3-12 days.

Patnaik and Pande (1965) described what they considered to be the endogenous stages of *E. ellipsoidalis* in the water buffalo. However, they were dealing with mixed infections, and it is uncertain that this is the species they were actually describing.

Prepatent Period. Hammond, Sayin and Miner (1962, 1963) found that the prepatent period in 31 calves was 8-13 (mean 10) days.

Type Host. *Bos taurus* (ox).

Other Hosts. *Bos indicus* (zebu); *Bubalus bubalis* (water buffalo). In addition, Yakimoff (1935b) reported it from the wisent or European bison *Bison bonasus*, the banteng *Bibos banteng* and the gayal *Bibos gayus* (syn., *Bos frontalis*).

Location. Small intestine (Boughton, 1945; Hammond, Sayin and Miner, 1962).

Geographic Distribution. North America (Alabama and other southeastern states, Illinois, Iowa, Montana, Oregon, Utah, Wisconsin), Central America (Costa Rica, Guatemala), South America (Colombia), Europe (Austria, Czechoslovakia, East Germany, England, Rumania, Yugoslavia, Spain), USSR (Azerbaijdzhan, Georgia, North Caucasus, Uzbekistan), Asia (Japan, Turkey, India), Africa (Nigeria, Senegal).

Pathogenicity. According to Boughton (1945), this species often caused nonbloody diarrhea in calves 1-3 months old. Hammond, Sayin and Miner (1962, 1963) observed diarrhea, usually lasting only a few days, in 26 of 31 2-4-week-old Holstein-Friesian calves inoculated with 50,000 to 1 million oocysts. The diarrhea was severe in 14 calves, moderate in 4 and slight in 9. Mucus was present in the feces at this time in most of the calves. The severe symptoms lasted only one day in 10 calves, and 2, 3, 6 and 8 days, respectively, in the others.

Of 11 calves subsequently challenged by Hammond, Sayin and Miner (1962, 1963) with 500,000 oocysts 52 days after the first inoculation, none had any clinical signs of coccidiosis; all but 4 (which had received only 50,000 oocysts initially) discharged markedly fewer oocysts than in the original infection, suggesting that some degree of immunity had developed.

Hammond, Sayin and Miner (1962, 1963) found serous inflammation of the ileum and jejunum of 4 calves killed 8-13 days after inoculation.

Hammond, Sayin and Miner (1963) found that the host cells of the endogenous stages were only slightly changed.

Cross-Transmission Studies. Sayin (1969) claimed to have infected 3 week-old calves (*Bos taurus*) with *E. ellipsoidalis* from the water buffalo.

Prevalence. Boughton (1945) found this species in 45% of 2,492 bovine fecal specimens in the southeastern U.S., Hasche and Todd (1959a) in 43% of 355 cattle in Wisconsin; Szanto, Mohan and Levine (1964) in 40% of 795 beef calves in Illinois; Nyberg, Helfer and Knapp (1967) in 33% of 86 cattle in Oregon; Jacobson and Worley (1969) in 14% of 486 calves and 3% of 479 adult cattle in Montana; Ruiz (1959) in 3% of 100 adult cattle and Ruiz and Ortiz (1961) in 4% of 100 calves in Costa Rica; Balconi (1963) in 47% of 100 adult cattle in Guatemala; Supperer (1952) in 15% of 130 cattle in Austria; Chroust (1964) in 34% of 184 calves in Czechoslovakia; Patyk (1965) in 13% of 341 calves in Poland; Joyner et al. (1966) in 26% of 110 cattle in England; Vassiliades (1969) in 12% of the cattle he examined in Senegal; Yakimoff, Gousseff and Rastegaieff (1932a) in 23% of 126 oxen in Uzbekistan; Yakimoff (1933a) in 27% of 41 oxen, 6% of 17 zebras and 52% of 21 water buffaloes in Azerbaidzhan; Marchenko (1937) in 16% of 137 cattle in North Caucasus; and Watanabe and Iwata (1956) in 0.4% of 454 cattle in Japan. Patnaik (1965) found it in 21% of 136 water buffaloes at Agra, India; Bhatia et al. (1968) in 20% of 305 water buffaloes at Mathura, Uttar Pradesh, India; and Sayin (1969) in 53% of 124 water buffaloes in Turkey.

Eimeria cylindrica Wilson, 1931

(PLATE 31, FIGS. 138-140; PLATE 62, FIG. 281)

[non] *Eimeria cylindrica* Ray and Das Gupta, 1936 (synonym of *E. gupti* Bhatia, 1938).

Description. Oocysts elongate ellipsoidal, with relatively straight sides. Oocyst wall colorless, smooth, composed of a single layer about $1.2\ \mu$ thick at the sides and bottom and about $0.7\ \mu$ thick at one end. (Bhatia et al., 1968, said that the oocyst wall was composed of 2 layers $1.3\ \mu$ thick in the water buffalo.) Micropyle inapparent. Oocysts 16-30 by 12-17 μ with a mean of 21-25 by 13-15 μ (oocysts in water buffalo 20-34 by 12-17 μ with a mean of 26 by 14 μ according to Bhatia et al., 1968). Oocyst residuum absent. Oocyst polar granule shattered into many small fragments. Sporocysts elongate ellipsoidal, with a thin to somewhat thick wall, with one end narrower than the other and truncate, but without a Stieda body. Sporocysts 12-16 by 4-6 μ with a mean of 14 by 5 μ (Levine and Ivens, 1967). (Sporocysts in water buffalo elongate ovoid, 9-13 by 4-6 μ with a mean of 10 by 5 μ , and with an inconspicuous Stieda body according to Bhatia et al., 1968.) Sporocyst residuum present in most sporocysts, composed of a ball of granules at one end of sporocyst. Sporozoites lie lengthwise head to tail in sporocysts. Sporozoites with one or more rather indistinct clear globules and a central vesicle which may be a nucleus.

Sporulation Time. According to Christensen (1941), sporulation took 2 days in water. Supperer (1952) found that it was 2-3 days.

Schizogony and Gametogony. Unknown.

Patnaik and Pande (1965) described what they considered to be the endogenous stages of *E. cylindrica* in the water buffalo. However, they were dealing with mixed infections, and it is uncertain that this is the species they were actually describing.

Prepatent Period. Wilson (1931) found oocysts in a calf from the 11th to 20th days after experimental inoculation.

Type Host. *Bos taurus* (ox).

Other Hosts. *Bos indicus* (zebu), *Bubalus bubalis* (water buffalo).

Location. Oocysts found in feces.

Geographic Distribution. North America (Alabama, Illinois, Montana, Oregon, Utah, Virginia, Wisconsin), Central America (Costa Rica, Guatemala), Europe (Austria, Czechoslovakia, England, Poland, Rumania, Yugoslavia), Asia (India), Africa (Nigeria, Senegal).

Pathogenicity. This species appears to be somewhat pathogenic. Wilson (1931) observed blood in the feces of an experimentally in-

fected calf 6 days after infection. Rao and Hiregaudar (1954a) considered this species pathogenic in zebu calves.

Cross-Transmission Studies. Wilson (1931) was unable to infect pigs or goats with this species.

Prevalence. Hasche and Todd (1959a) found this species in 20% of 355 cattle in Wisconsin; Szanto, Mohan and Levine (1964) in 12% of 795 beef calves in Illinois; Nyberg, Helfer and Knapp (1967) in 10% of 86 cattle in Oregon; Jacobson and Worley (1969) in 2% of 486 calves and none of 486 adult cattle in Montana; Ruiz (1959) in 1% of 100 adult cattle in Costa Rica; Balconi (1963) in 19% of 100 adult cattle in Guatemala; Supperer (1952) in 4% of 130 cattle in Austria; Chroust (1964) in 8% of 184 calves in Czechoslovakia; Patyk (1965) in 3% of 341 calves in Poland; Joyner et al. (1966) in 13% of 110 cattle in England; and Vassiliades (1969) in 6% of the cattle he examined in Senegal. Patnaik (1965) reported it in 7% of 136 water buffaloes in Agra, India; and Sayin (1969) in 5% of 124 water buffaloes in Turkey.

Remarks. It is possible that the form in water buffaloes is a different species since its oocysts and sporocysts differ to some extent in structure (Bhatia et al., 1968).

Eimeria auburnensis Christensen and Porter, 1939

(PLATE 32, FIGS. 141-143; PLATE 33, FIGS. 144-147; PLATE 34, FIGS. 148-154; PLATE 35, FIGS. 155-160; PLATE 36, FIGS. 161-167; PLATE 37, FIG. 168; PLATE 38, FIGS. 169-170; PLATE 39, FIG. 171; PLATE 40, FIG. 172; PLATE 41, FIG. 173; PLATE 42, FIG. 174; PLATE 43, FIG. 175; PLATE 63, FIG. 284)

Eimeria ildefonsoi Torres and Ramos, 1939.

Eimeria khurodensis Rao and Hiregaudar, 1954.

Eimeria sp. Pop-Cenitch and Bordjochki, 1959.

Description. Oocysts elongate ovoid (varying between almost ellipsoidal and markedly tapered), somewhat flattened at small end. Micropyle present at small end. Oocyst wall smooth, rarely rough or heavily mammillated, 1.0-1.8 μ thick, becoming thinner at micropylar end. Oocyst wall composed of one layer lined by a thin membrane which is slightly wrinkled at the micropylar end (Levine and Ivens, 1967) or composed of 2 layers lined by a thin membrane (Nyberg and Hammond, 1965); outer part or layer of oocyst wall yellowish orange (Levine and Ivens, 1967) or colorless to pink-orange or lavender (Ny-

berg and Hammond, 1965); inner part or layer greenish (Levine and Ivens, 1967) or orange-green (Nyberg and Hammond, 1965). (Christensen and Porter, 1939 described the wall as typically smooth, homogeneous, transparent, noticeably brownish-yellow.) Oocysts 32-46 by 19-28 μ with means given by various authors ranging from 36-41 by 22-26 μ . Oocyst polar granule present, composed of one large and many small, shattered fragments. Oocyst residuum absent. Sporocysts elongate, almost ellipsoidal, but with one end smaller than the other. Stieda body present, not prominent. Sporocyst wall about 0.2 μ thick. Sporocyst residuum present. Sporocysts 16-23 by 7-11 μ with means given by different authors ranging from 18-19 by 8-9 μ . (Svanbaev, 1967a gave a range of 15-17 by 6-7.5 μ with a mean of 16 by 6 μ .) Sporozoites elongate, rather comma-shaped, lying lengthwise head to tail in sporocysts, with one large clear globule in the large end and sometimes one or 2 smaller globules elsewhere. Sporozoites 15-18 by 3-5 μ with a mean of 16 μ long, 5 μ wide at the large end and 4 μ wide at the small end (Nyberg and Hammond, 1965).

Christensen and Porter (1939) said that the typical oocysts were smooth, but that some were heavily mammillated and others were intermediate between the 2 types. In an infection experiment, they produced both smooth and mammillated oocysts by feeding the latter to a calf; the smooth oocysts predominated.

Sporulation Time. Christensen and Porter (1939) found that the sporulation time in tap water at room temperature was 2-3 days; Supperer (1952) reported the same sporulation time; Lee and Armour (1959) reported the same time at 27 C.

Schizogony and Gametogony. Hammond, Clark and Miner (1961) and Davis and Bowman (1962) were the first to describe the endogenous stages in the life cycle of *E. auburnensis*. The latter found giant schizonts in the middle and lower third of the small intestine of 2 calves killed 12 and 14 days after experimental infection. (Chobotar and Hammond, 1967, found them throughout the small intestine but mostly 6-12 m anterior to the ileocecal valve.) They were 78-250 by 48-150 μ with a mean of 140 by 92 μ . They were usually located in cells of the reticular connective tissue deep in the lamina propria near the muscularis mucosae. Chobotar and Hammond (1967) found them in the epithelial cells lining the crypts of Lieberkuehn, usually at or near the base of the crypt. (In contrast, the giant schizonts of *E. bovis* are found in the endothelial cells lining the lacteals of the villi.) They matured 10 days after inoculation (Chobotar, Hammond and Miner, 1969), being 134-338 by 95-172 μ with a mean of 178 by 114 μ at that time, containing thousands of merozoites and occupying the

whole width of the crypt. The host cell nucleus enlarged. Each schizont lay in a parasitophorous vacuole in the host cell. The mature merozoites within the schizonts were about $11\ \mu$ long (they measured 4-11 μ with a mean of 8 μ , but Davis and Bowman said that they were unable to measure their full length because of their position in the sections). They had a compact nucleus at one end.

Chobotar (1968) found mature second generation schizonts 12-14 days after inoculation in cells of the lamina propria under the villar epithelium of the small intestine. They were 6-12 by 5-9 μ with a mean of 8.5 by 6 μ and contained 4-11 (mean 7) merozoites each. The second generation merozoites were spindle-shaped, 7-9 by 1-2 μ with a mean of 8 by 1.5 μ , and contained a vesicular nucleus in the broader posterior end of the body. Their host cells were only slightly altered.

The gamonts occur in the subepithelium in mesenchymal-mesodermal cells of the small intestine (Hammond, Clark and Miner, 1961, Chobotar, 1968). Davis and Bowman (1962) found many more microgamonts near the muscularis mucosae than in the villi; 16 out of 20 randomly selected ones were in the basal half of the mucosa. Hammond, Clark and Miner (1961) found gamonts of both sexes 14-18 days after infection, and Davis and Bowman (1962) found microgamonts 12-14 days after infection. They were very large. Hammond, Clark and Miner (1961) reported that the mature microgamonts were 67-103 by 48-83 μ with a mean of 85 by 65 μ and that each contained thousands of microgametes. Davis and Bowman (1962) found that the mature microgamonts were 36-288 by 27-150 μ with a mean of 125.5 by 79.5 μ . Chobotar (1968) said that mature microgamonts at 18-19 days were 61-151 by 42-109 μ with a mean of 103 by 70 μ .

According to Hammond, Clark and Miner (1961), the microgametes were 4-8 μ long with a mean of 5.5 μ , 0.5-0.75 μ wide, and had 2 posteriorly directed flagella about 10-12 μ long.

According to Hammond, Clark and Miner (1961), the macrogametes were about 18 μ long at 18 days, being considerably smaller than the microgamonts.

Scholtyssek, Hammond and Ernst (1966) described the fine structure of the macrogametes. They contain closely spaced glycogen granules 0.3-1.0 μ in diameter, mostly joined at the margins with one or more adjacent granules. The dark bodies are larger than those of *E. bovis*, averaging 1.5 μ in greater diameter. The wall-forming bodies are slightly larger than the dark bodies, averaging 1.7 μ in diameter. This species is distinguished by having groups of microtubules, usually several layers deep in some places and few or none in others. The parasitophorous vacuole is relatively large and is filled with amorphous

electron-dense material. There are numerous mitochondria in the host near the vacuole. Scholtyseck, Hammond and Chobotar (1967) described pinocytosis in *E. auburnensis* macrogametes.

Hammond, Scholtyseck and Miner (1967) described the fine structure of the microgamonts. They contain thousands of irregularly distributed nuclei which never become arranged at the surface. They do not contain typical endoplasmic reticulum or glycogen granules, but do contain large and small vacuoles, mostly with thick walls, and either empty or containing electron-dense material. The parasitophorous vacuole is well developed around growing microgamonts, but narrow or nonexistent around mature ones; it contains parasite mitochondria enclosed in a thin layer of parasite cytoplasm. The interior of the microgamonts contains furrows which become confluent in later stages, separating the cytoplasm into many small masses with relatively large interstitial spaces. As the microgamete flagella developed, they were seen in these spaces.

Hammond, Ernst and Chobotar (1967) and Hammond, Chobotar and Ernst (1968) described the sporozoites of *E. auburnensis*. They are broadly lanceolate, 16-21 by 3.5-5 μ with a mean of 18.7 by 4.5 μ and move by gliding and flexion. They have a relatively large refractile body at the posterior end and one or more smaller refractile bodies anterior to the nucleus. The nucleus is vesicular, near the center of the body, and has a somewhat eccentric nucleolus and peripheral chromatin. There is a nipple-like projection at the anterior end, some indication of peripheral fibrils and occasionally median rodlike bodies interpreted as paired organelles (rhoptries). There is a small spherical structure resembling a refractile body at the extreme posterior end. There are numerous glycogen granules, mostly in the middle of the sporozoite.

Hammond, Clark and Miner (1961) found oocysts in the lamina propria of calves killed 18-19 days after inoculation.

Chobotar and Hammond (1967) found schizonts as early as 6 days after inoculation.

Patnaik and Pande (1965) and Bhatia and Pande (1967a) described what they considered to be the endogenous stages of *E. auburnensis* in the small intestine of the water buffalo. However, they were dealing with mixed infections, and it is uncertain that this is the species that they were actually describing.

Prepatent Period. Christensen and Porter (1939) reported that the prepatent period in one calf was 24 days; it discharged large numbers of oocysts for 3 days and small numbers for the next few weeks. Hammond, Clark and Miner (1961) found that the prepatent period in 22

calves was 18-20 days, being 18 days in the great majority. The patent period was 2-7 days. Svanbaev (1967a) found that the prepatent period was 18-19 days and the patent period 8 days in 2 calves. Chobotar (1968) found that the prepatent period was 16-17 days and the patent period 2-4 days.

Type Host. *Bos taurus* (ox).

Other Hosts. *Bos indicus* (zebu); *Bubalus bubalis* (water buffalo).

Location. Middle and lower third of small intestine.

Geographic Distribution. USA (Alabama, southeastern states, Illinois, Missouri, Oregon, Texas, Utah, Wisconsin, Wyoming), Central America (Costa Rica, Guatemala), South America (Brazil, Colombia), Europe (Austria, Czechoslovakia, England, Rumania, Spain, Yugoslavia), Asia (India, Japan, Turkey), USSR (Kazakhstan), Africa (Nigeria, Senegal).

Pathogenicity. This species apparently has a moderate degree of pathogenicity. Christensen and Porter (1939) produced a profuse, watery green diarrhea accompanied by slight apathy in a 2-week-old calf by administering 8,000 sporulated oocysts. The signs appeared 9 days after infection (i.e., 15 days before the first oocysts appeared in the feces) and continued for 5 days. According to Davis and Bowman (1952), infections with *E. auburnensis* are usually accompanied by straining and the passage of visible blood and mucus, especially following experimental inoculation with large numbers of oocysts or in natural outbreaks where contamination is heavy. Hammond, Clark and Miner (1961) reported that 4 calves 1-6 weeks old inoculated with 100,000-750,000 oocysts discharged moderate to high numbers of oocysts (about 14,000-200,000 per gram of feces); one had severe diarrhea 18-20 days after inoculation, 2 had mild diarrhea 18-19 days after inoculation, and one showed no signs of coccidiosis. Davis and Bowman (1962) reported that a month-old calf had diarrhea 6-12 days after inoculation; at autopsy on the 12th day, its small intestine was edematous 7 m anterior to the ileocecal valve.

Cross-Transmission Studies. Sayin (1969) claimed to have infected 3 week-old calves (*Bos taurus*) with *E. auburnensis* from the water buffalo.

Prevalence. *E. auburnensis* is one of the commonest coccidia of cattle in North America. Davis and Bowman (1952) found it in all of 20 calves in Alabama; Hasehe and Todd (1959a) in 45% of 355 cattle in Wisconsin; Szanto, Mohan and Levine (1964) in 46% of 795 beef calves in Illinois (originating from Illinois, Missouri, Texas and Wyoming); Nyberg, Helfer and Knapp (1967) in 14% of 86 cattle in Oregon; Jacobson and Worley (1969) in 32% of 486 calves

and 12% of 479 adult cattle in Montana; Torres and Ramos (1939) in 32% of 146 cattle in Brazil; Supperer (1952) in 3% of 130 cattle in Austria; Watkins (according to Lapage, 1956) in 91% of the calves he examined in Devonshire, England; Joyner et al. (1966) in 34% of 110 cattle in England; Marinkelle (1964) in 32% of 100 calves in Colombia; Ruiz and Ortiz (1961) in 1% of 100 calves in Costa Rica; Balconi (1963) in 43% of 100 adult cattle in Guatemala; Watanabe, and Iwata (1956) in 2% of 454 cattle in Japan; Chroust (1964) in 18% of 184 calves in Czechoslovakia; Patyk (1965) in 15% of 341 calves in Poland; and Vassiliades (1969) in 12% of the cattle he examined in Senegal. Svanbaev (1967a) found it in a calf as early as 30 days after birth; he found it in 5% of 781 cattle 2 months to more than a year old in Kazakhstan. Lee and Armour (1959) said that it was very common at Vom, Nigeria. Patnaik (1965) reported *E. auburnensis* in 19% of 136 water buffaloes at Agra, India, Bhatia et al. (1968) in 32% of 305 water buffaloes at Mathura, Uttar Pradesh, India; and Sayin (1969) in 44% of 124 water buffaloes in Turkey.

Remarks. The name *Eimeria ildefonsoi* Torres and Ramos (1939) is now accepted as a synonym of *E. auburnensis*. (See Levine, 1961; Pellérdy, 1965.) Patnaik (1965) thought that *E. khurodensis* Rao and Hiregaudar (1954a) was a synonym of *E. thianethi*, but Levine and Ivens (1967) showed that it was a synonym of *E. auburnensis*. Hiregaudar and Rao (1966) insisted that *E. khurodensis* was different from *E. bukidnonensis*, but there was nothing in their description that could be used to differentiate it from the mammillated form of *E. auburnensis* except that they gave its sporulation time as 10-15 days as opposed to 2-3 days for *E. auburnensis*. However, sporulation times are subject to wide variation depending on the circumstances of sporulation. If this species is indeed distinct from *E. auburnensis*, a far better description than has heretofore been provided must be given. Pellérdy (1965) and Bhatia et al. (1968) stated that *E. bombayansis* Rao and Hiregaudar (1954a) is a synonym of *E. auburnensis*; this may well be true, but the size given for the sporocysts of *E. bombayansis* is smaller than that of *E. auburnensis*.

Pop-Cenitch and Bordjochki (1959) described an *Eimeria* sp. from cattle in Serbia which Pellérdy (1965) considered to be *E. auburnensis*; we agree.

***Eimeria brasiliensis* Torres and Ramos, 1939**

(PLATE 44, FIGS. 176-178; PLATE 45, FIGS. 179-180; PLATE 61, FIGS. 269-270; PLATE 63, FIG. 285)

Eimeria boehmi Supperer, 1952.

Eimeria orlovi Basanova, 1952.

Eimeria helenae Donciu, 1961.

Description. Oocysts ellipsoidal, 31-49 by 21-33 μ with means of 36-38 by 25-27 μ (31 to 44 by 20-29 μ with a mean of 39 by 27 μ in the water buffalo according to Bhatia et al., 1968). Micropyle present, covered by a mound-shaped or flat cap about 1.5-4 μ high and 7-12 μ wide. Oocyst wall generally smooth, brownish yellow, generally composed of a single layer 1.8 μ thick at the sides and 1 μ thick at the end opposite the micropyle. (Two layers 1.3 μ thick in the water buffalo according to Bhatia et al., 1968.) Oocyst wall lined by a brownish membrane. Surface of oocyst occasionally covered by round, partially coalescent yellowish plaques about 5 μ in diameter (each presumably originating from a flattened plastic granule) which form an incomplete additional layer on the surface, giving it a rough appearance; some of these plaques may be partially scaled off of the oocysts. Oocyst residuum and polar granule generally absent, but tiny scattered granules present in some oocysts and some amorphous material in others. Polar granules present according to Torres and Ramos (1939). "Tenue body" (i.e., polar granule) just beneath micropyle in sporulated and unsporulated oocysts in the water buffalo according to Bhatia et al. (1968). Sporocysts elongate ellipsoidal, with relatively narrow ends, 16-22 by 7-10 μ . Definite Stieda body absent, but represented by a dark, thickened wall at one end of sporocyst. Sporocyst residuum composed of more or less scattered granules. Sporozoites elongate, lying head to tail in sporocysts, with one large clear globule at each end. (See figures by Marquardt, 1959, and Levine and Ivens, 1967.)

Sporulation Time. The sporulation time is 6-7 days at 27 C according to Lee and Armour (1958), 12-14 days at 20 C according to Supperer (1952), or 7-8 days at 25-28 C in 2% potassium bichromate solution according to Svanbaev (1967a).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bos taurus* (ox).

Other Hosts. *Bos indicus* (zebu); *Bubalus bubalis* (water buffalo).

Location. Oocysts found in feces. Svanbaev (1967a) said that this species occurs in the anterior ileum.

Geographic Distribution. North America (Alabama, Illinois, Montana, Wisconsin), Central America (Guatemala), South America (Brazil), Europe (Austria, England, Hungary, Rumania, Yugoslavia), Africa (Nigeria, Senegal), Asia (India), USSR (Kazakhstan).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Hasehe and Todd (1959a,b) found this species in 3% of 355 cattle in Wisconsin; Szanto, Mohan and Levine (1964) in 4% of 795 beef calves in Illinois; Jacobson and Worley (1969) in none of 486 calves and 0.2% of 479 adult cattle in Montana; Torres and Ramos (1939) in 3% of 146 cattle in Brazil; Balconi (1963) in 3% of 100 adult cattle in Guatemala; Joyner et al. (1966) in 7% of 110 cattle in England; Supperer (1952) in 7% of 130 cattle in Austria; Doneiu (1961) in 0.4% of 2,183 cattle in Rumania; and Vassiliades (1969) in 2% of the cattle he examined in Senegal. Svanbaev (1967a) found it in a calf as early as 30 days after birth; he found it in 4% of 781 cattle 2 months to more than a year old in Kazakhstan. Bhatia et al. (1968) found this species in 2% of 305 water buffaloes in Mathura, Uttar Pradesh, India; and Sayin (1969) in 1.6% of 124 water buffaloes in Turkey.

Remarks. Bhatia et al. (1968) considered that *E. gokaki* was a synonym of *E. brasiliensis*, but it is smaller and we prefer to leave it as a separate species, at least for the present.

Eimeria alabamensis Christensen, 1941

(PLATE 45, FIGS. 181-184; PLATE 62, FIG. 278)

Description. Oocysts ovoid, but with sides rather tapering toward small end. Micropyle absent. Oocyst wall smooth, very pale yellow, composed of a single layer about 0.6-0.7 μ thick, lined by a thin membrane which may collapse at the small end after standing in Sheather's sugar solution (2 layers 1.3 μ thick in the water buffalo according to Bhatia et al., 1968). Oocysts 13-25 by 11-17 μ . Oocysts polar granule and oocyst residuum absent, except for some tiny scattered fragments which might or might not be polar granule fragments. Sporocysts elongate, with one end bullet-like and bearing a tiny Stieda body, without sporocyst residuum. Sporocysts 11-16 by 4-5 μ with a mean of 11.9 by 4.6 μ . (8-11.5 by 5-6 μ with a mean of 9 by 5 μ according to Svanbaev, 1967a.) Sporozoites lie lengthwise, head to tail, in sporocysts. Sporozoites with 2-3 clear globules. (See figure by Levine and Ivens, 1967.)

Sporulation Time. Christensen (1941) and Lee and Armour (1959) reported that the sporulation time was 4-5 days in water at room temperature and 27 C, respectively; Svanbaev (1967a) found that it was 4-5 days at 25-28 C in 2% potassium bichromate solution.

Schizogony and Gametogony. Davis, Bowman and Boughton (1957) described the endogenous life cycle of *E. alabamensis*. It took place in the nucleus of the intestinal cells. The sporulated oocysts excysted in the rumen, omasum and small intestine. The sporozoites entered the epithelial cells of the villi of the small intestine, where they rounded up and became schizonts; they were generally in the distal end of the host cell but then entered the nucleus, where they were found 2 days after infection. At first the sporozoites were spindle-shaped and 3-7 by 1.5-3 μ ; when they rounded up they were 2.8-3.5 μ in diameter with a mean of 3.1 μ . The young schizonts were in the apical cells of the tips of the villi, and were almost always surrounded by a clear, halo-like area.

The schizonts then grew, becoming mature at 3 days. Mature schizonts containing merozoites were found 3-8 days after infection. At 4 days they were found only in the lowest third of the small intestine. They were numerous at this time, but became fairly sparse by the 8th day. One to several schizonts were present in each host cell nucleus. The mature schizonts were 7-12 by 6-10 μ at 3 days, 8-15 by 7-12 μ at 4 days, 10-15 by 7-13 μ at 6 days, and 8-18 by 5-14 μ at 8 days. They contained 16-32 merozoites; occasionally a host cell nucleus contained 48 merozoites, but these were apparently derived from more than one schizont.

It is probable that there is more than one asexual generation; Davis, Bowman and Boughton (1957) found merozoites penetrating host cell nuclei in the lower small intestine as early as 4 days after infection and said that "they probably developed into other schizonts or initiated gametogenesis."

Gamonts were formed in the nuclei of the epithelial cells of the villi of the small intestine; in heavy infections they also occurred in the cecum and upper colon. They could be recognized as early as 6 days after infection. The ratio of macrogametes to microgamonts was 78:22. Two or 3 microgamonts and 3-5 macrogametes or oocysts per host cell nucleus were not uncommon. The microgamonts were 8-25 by 7-21 μ with a mean of 15.6 by 11.5 μ . The macrogametes were 7-20 by 7-12 μ with a mean of 12 by 9.1 μ and contained peripheral plastic granules.

Oocysts were present beginning 6 days after infection in the lower 7 m of the ileum.

Prepatent Period. According to Davis, Boughton and Bowman (1955), the prepatent period in 21 low-grade infections ranged from 6-11 days with a mean of 8.6 days. The patent period was 1-10 days with a mean of 4.6 days. The period of high oocyst discharge was

1-9 days with a mean of 3.9 days. Smith and Davis (1965) found that the prepatent period was 7-9 days whether the oocysts were given to calves in dry feed or liquid. The patent period was 5-13 days in the former and only 1-8 days in the latter. Svanbaev (1967a) found that the prepatent period was 7-8 days and the patent period 9 days in 2 calves.

Type Host. *Bos taurus* (ox).

Other Hosts. *Bos indicus* (zebu); *Bubalus bubalis* (water buffalo).

Location. Primarily small intestine, but also cecum and upper colon in heavy infections.

Geographic Distribution. USA (Alabama, southeastern states, Illinois, Oregon, Missouri, Montana, Texas, Utah, Wisconsin, Wyoming), Central America (Costa Rica, Guatemala), Europe (England, Poland), Asia (Turkey), USSR (Kazakhstan), Africa (Nigeria, Senegal).

Pathogenicity. According to Davis, Boughton and Bowman (1955), *E. alabamensis* is essentially nonpathogenic under field conditions. However, it may or may not cause symptoms in the laboratory. Boughton (1943) found that it was pathogenic and even caused the death of 2 out of 5 calves 8 and 14 days after infection when large numbers (many millions) of oocysts were given. Davis, Boughton and Bowman (1955) found that it also caused severe nonfatal infections in 2 previously unexposed 14-month-old cattle and in a 2-year-old cow. (The above were mixed infections with other unspecified species of *Eimeria*.) According to Davis, Bowman and Boughton (1957), there was general enteritis in the lower half of the small intestine of one of the 2 calves that died and in the last meter of the ileum of the other. There was also massive destruction of the epithelium, with leucocytic infiltration and villar edema. Clusters of swollen villi formed macroscopically visible tufts, and in severe infections nearly all villi in a 7 meter length of small intestine were infected.

Cross-Transmission Studies. None.

Prevalence. Davis, Boughton and Bowman (1955) found this species in 93% of 102 dairy calves in 6 herds in southeastern United States in a weekly fecal survey; they found it in 24% of 135 animals from which only a single fecal sample was taken; it was present in all of 26 herds from which at least 5 animals were examined. Hasche and Todd (1959a) found it in 42% of 355 cattle in Wisconsin; Szanto, Mohan and Levine (1964) in 17% of 795 cattle from Illinois, Missouri, Texas and Wyoming; Nyberg, Helfer and Knapp (1967) in 1% of 86 cattle in Oregon; Jacobson and Worley (1969) in 0.4% of 486 calves and none of 479 adult cattle in Montana, Joyner et al. (1966) in 14% of 110 cattle in England; Patyk (1965) in 9% of 341 calves in Poland;

Ruiz and Ortiz (1961) in 20% of 100 calves in Costa Rica. Balconi (1963) in 43% of 100 cattle in Guatemala, and Vassiliades (1969) in 2% of the cattle he examined in Senegal. Patnaik (1965) reported it in 1% of 136 water buffoles in Agra, India; Bhatia et al. (1968) in 3% of 305 water buffaloes at Mathura, Uttar Pradesh, India, and Sayin (1969) in 10% of 124 water buffaloes in Turkey. Svanbaev (1967a) found it in a calf as early as 10 days after birth; he found it in 8% of 781 calves 2 months to more than a year old in Kazakhstan.

Davis, Boughton and Bowman (1955) found that under farm conditions *E. alabamensis* was relatively rare in calves 3-9 weeks old and relatively common in those 3-9 months old.

***Eimeria subspherica* Christensen, 1941**

(PLATE 46, FIGS. 186-189; PLATE 62, FIG. 279)

Description. Oocysts spherical to subspherical. Oocyst wall smooth, pale yellowish, composed of a single layer about 0.5-0.6 μ thick. (Two layers 0.7-1.0 μ thick in the water buffalo according to Bhatia et al., 1968.) Micropyle absent. Oocysts 9-14 by 8-13 μ with a mean of 11-13 by 10-12 μ (Christensen, 1941; Lee and Armour, 1959; Levine and Ivens, 1967). Oocyst residuum and oocyst polar granule absent. Sporocysts elongate ovoid, often with rather flat sides, with small Stieda body, 7-10 by 3-4 μ with a mean of 8 by 3.5 μ (Levine and Ivens, 1967). Sporocyst residuum absent or occasionally composed of a few granules. Sporozoites wider at one end than the other, lying lengthwise head to tail in sporocysts. Sporozoites with a clear globule at the large end.

Sporulation Time. Four to 5 days in water at room temperature according to Christensen (1941).

Schizogony and Gametogony. Unknown.

Patnaik and Pande (1965) described the endogenous stages of a coccidium that they tentatively identified as *E. subspherica* in the water buffalo. However, they were dealing with mixed infections, and it is uncertain that this is the species that they actually saw.

Prepatent Period. Unknown.

Type Host. *Bos taurus* (ox).

Other Hosts. *Bos indicus* (zebu); *Bubalus bubalis* (water buffalo).

Location. Oocysts found in feces.

Geographic Distribution. North America (Alabama, Illinois, Oregon, Utah, Wisconsin), Central America (Costa Rica, Guatemala), South

America (Colombia), Europe (England, East Germany), Asia (Turkey, India), Africa (Nigeria, Senegal).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Hasche and Todd (1959a) found this species in 11% of 355 cattle in Wisconsin; Szanto, Mohan and Levine (1964) in 8% of 795 beef calves in Illinois; Nyberg, Helfer and Knapp (1967) in 8% of 86 cattle in Oregon; Ruiz and Ortiz (1961) in 3% of 100 calves in Costa Rica; Balconi (1963) in 12% of 100 adult cattle in Guatemala; Joyner et al. (1966) in 28% of 110 cattle in England, and Vassiliades (1969) in 6% of the cattle he examined in Senegal. Patnaik (1965) reported this species in 21% of 136 water buffaloes in Agra, India; Bhatia et al. (1968) in 16% of 305 water buffaloes in Mathura, Uttar Pradesh, India; and Sayin (1969) in 15% of 124 water buffaloes in Turkey.

Eimeria wyomingensis Huizinga and Winger, 1942

(PLATE 48, FIG. 198; PLATE 49, FIGS. 199-200; PLATE 62, FIG. 274)

? *E. bukidnonensis* Tubangui, 1931 of Christensen, 1938a.

[non] *E. bukidnonensis* Tubangui, 1931.

Description. Oocysts ovoid. Oocyst wall yellowish brown to brownish yellow, speckled and somewhat rough, composed of a single layer about 2.0-3.5 μ thick, lined by a membrane. Micropyle present, about 5 μ in inside diameter, at small end of oocyst, generally sunken. Oocysts 36-46 by 26-32 μ with a mean of 40 by 28 μ (Huizinga and Winger, 1942; Lee and Armour, 1959). Oocyst residuum and polar granule absent. Sporocysts ellipsoidal, with somewhat narrow ends, with a tiny flat Stieda body at one end. Sporocysts about 18 by 9 μ (sporocysts in the water buffalo 21-24 by 8-9 μ with a mean of 22 by 9 μ according to Bhatia et al., 1968). Sporocyst residuum generally absent; sometimes present in form of granules. Sporozoites with one end wider than the other, lying lengthwise head to tail in sporocysts. Sporozoites with a large, clear globule about 7-8 μ long by 5 μ at broader end.

Sporulation Time. Five to 7 days at room temperature in shallow, dilute potassium bichromate solution, according to Huizinga and Winger (1942); 3-5 days at 27 C in water, according to Lee and Armour (1959).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bos taurus* (ox).

Other Hosts. *Bos indicus* (zebu), *Bubalus bubalis* (water buffalo).

Location. Oocysts found in feces.

Geographic Distribution. North America (Alabama?, Illinois, Texas, Wyoming), Europe (England, Poland), Africa (Nigeria, Senegal), Asia (India).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Szanto, Mohan and Levine (1964) found this species in 6% of 795 beef calves in Illinois; these animals had originated in Illinois, Texas and Wyoming. Joyner et al. (1966) found it in 14% of 110 cattle in England; Patyk (1965) in 1% of 341 calves in Poland, and Vassiliades (1969) in 1% of the cattle he examined in Senegal. Bhatia et al. (1968) found it in 5% of 305 water buffaloes in Mathura, Uttar Pradesh, India, and Sayin (1969) in 0.7% of 124 water buffaloes in Turkey.

Remarks. This species has been confused with *E. bukidnonensis*, but Levine and Ivens (1967) clarified the difference. *E. wyomingensis* differs from *E. bukidnonensis* in that it has smaller oocysts that are ovoid rather than piriform, and in that its wall, although brownish and rough, is not radially striated.

Eimeria pellita Supperer, 1952

(PLATE 48, FIGS. 194 and 195)

Description. Oocysts ovoid with a flattened small end, 36-41 by 26-30 μ . Micropyle at small end. Oocyst wall relatively thick and dark brown, bearing numerous small, uniformly distributed protuberances on its surface in the form of small, blunt points which give the wall a velvety appearance. Oocyst polar granule and oocyst residuum absent. Sporocysts elongate ovoid, 14-18 by 6-8 μ , without a Stieda body. Sporocyst residuum present, usually compact. Sporozoites lie lengthwise head to tail in sporocysts. Sporozoites with 2 refractile globules (Supperer, 1952).

Sporulation Time. Ten to 12 days according to Supperer (1952).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bos taurus* (ox).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Europe (Austria, England).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Supperer (1952) found this species in 5% of 130 cattle in Austria, and Joyner et al. (1966) in 4.5% of 110 cattle in England.

Remarks. Bhatia et al. (1968) considered *E. pellita* a synonym of *E. bukidnonensis*. However, the structure of its oocyst wall and shape of its oocyst differentiate it (See Joyner et al., 1966).

Eimeria illinoisensis Levine and Ivens, 1967

(PLATE 49, FIG. 201)

Description. Oocysts ellipsoidal or slightly ovoid. Oocyst wall smooth, colorless, composed of a single layer about $1.3\ \mu$ thick, with a pale tan inner surface which looks like a membrane in the intact oocyst. Definite micropyle absent, but one end of oocyst wall slightly thinner and flatter, with darker boundaries, than the other. Oocysts 24-29 by 19-22 μ with a mean of 26 by 21 μ . Oocysts residuum and oocyst polar granule absent. Sporocysts elongate ovoid, with one end slightly tapered and slightly smaller than the other, with a small, flat to knoblike (in isolated sporocyst) Stieda body. Sporocysts 13-16 by 6-7 μ with a mean of 15 by 6.5 μ . Sporocyst residuum generally a compact, granular ball plus some scattered granules. Sporozoites with one end larger than the other, lying lengthwise head to tail in sporocysts. Sporozoites with 2 or more clear globules.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bos taurus* (ox).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. North America (Illinois).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Eimeria bukidnonensis Tubangui, 1931

(PLATE 46, FIG. 185; PLATE 47, FIGS. 190-193)

Description. Oocysts piriform. Micropyle about 3-5 μ in diameter at small end of oocyst, more or less sunken in sporulated oocysts but

not in unsporulated ones. Oocyst wall yellowish brown, punctate, radially striated, composed of a single layer about 3-4 μ thick, lined by a rather thick membrane which may be slightly wrinkled at the small end. Oocysts 43-54 by 29-39 μ . (Svanbaev, 1967a, gave dimensions of 34-50 by 26-34 μ with a mean of 39 by 30 μ ; he may have been dealing with a mixture of *E. bukidnonensis* and *E. wyomingensis*.) (Oocysts in water buffalo 38-46 by 25-35 μ with a mean of 42 by 31 μ according to Bhatia et al., 1968.) Oocyst residuum and polar granule absent. Sporocysts elongate, somewhat pointed at both ends, with inconspicuous flat Stieda body, about 20 by 10 μ . (12-20 by 9-12 μ according to Svanbaev, 1967.) (Sporocysts in water buffalo 15-19 by 8-11 μ with a mean of 17 by 9 μ according to Bhatia et al., 1968.) Sporocyst residuum absent or perhaps represented by a few tiny, scattered granules. (According to Hiregaudar and Rao, 1966 and Bhatia et al., 1968, there is a large amount of sporocyst residual material.) Sporozoites with one end wider than the other, lying lengthwise head to tail in sporocysts. Sporozoites with a clear globule at each end. (See figure by Levine and Ivens, 1967.)

Sporulation Time. According to Baker (1939), the sporulation time is 24-27 days; according to Lee (1954) it is 17 days at room temperature, and according to Lee and Armour (1959) it is 5-7 days at 27 C; it is 4-8 days according to Hiregaudar and Rao (1966). Svanbaev (1967a) said that it was 5-9 days at 25-28 C in 2% potassium bichromate solution.

Schizogony and Gametogony. Unknown. Davis and Bowman (1964) found many merozoites 9-13 μ long throughout the small intestine of a calf 13 days after oral infection at one week of age with 1 million oocysts. They found oocysts in the small intestine 0.3 m anterior to the ileocecal valve in another calf 25 days after infection at 3 months of age with 60,000 oocysts. They were beneath the epithelium about half-way down to the muscularis mucosae.

Prepatent Period. Baker (1939) found that oocysts first appeared in an experimentally infected calf 10 days after inoculation. Davis and Bowman (1964) found that the prepatent period was 15-17 days in 7 calves. Svanbaev (1967a) found that it was 24-25 days in 2 calves.

Type Host. *Bos indicus* (zebu).

Other Hosts. *Bos taurus* (ox). In addition, Yakimoff (1935b) reported finding a single oocyst (which he called *E. bukidnonensis*) in a banteng *Bibos banteng*; it was 39 by 27 μ . Patnaik (1965) and Bhatia et al. (1968) found it in water buffaloes (*Bubalus bubalis*) in India.

Location. Oocysts found in feces. Svanbaev (1967a) said that it occurred in the middle and posterior ileum.

Geographic Distribution. North America (New York, Illinois, Montana), Europe (England, East Germany, Poland), Asia (Philippines, India, Japan, Turkey), South America (Brazil), Africa (Nigeria), USSR (Azerbaijan, Kazakhstan, Turkestan, Uzbekistan).

Pathogenicity. Baker (1939) observed a tendency toward a diarrheic condition from the 7th to 15th days after experimental inoculation of a 70-day-old calf with 55 oocysts.

Cross-Transmission Studies. None.

Prevalence. Since earlier authors failed to differentiate between *E. bukidnonensis* and *E. wyomingensis*, little can be said about the prevalence of either species. Szanto, Mohan and Levine (1964) found it in 1% of 795 beef calves in Illinois; Jacobson and Worley (1969) in 9% of 486 calves and 4% of 479 adult cattle in Montana; Joyner et al. (1966) in 2% of 110 cattle in England; and Patyk (1965) in 3% of 341 calves in Poland. Patnaik (1965) reported it from 3% of 136 water buffaloes in Agra, India, and Bhatia et al. (1968) in 5% of 305 water buffaloes in Mathura, Uttar Pradesh, India. Svanbaev (1967a) found it in a calf as early as 40 days after birth; he found it in 9% of 781 cattle 2 months to more than a year old in Kazakhstan.

Remarks. The oocysts that Patnaik (1965) found in the water buffalo were said to be considerably smaller than the minimum range given by other authors, but Patnaik gave no measurements. Whether he was dealing with a different species remains to be determined.

Bhatia et al. (1968) considered *E. pellita*, *E. thianethi*, *E. mundaragi* and *E. khurodensis* to be synonyms of *E. bukidnonensis*. We consider the first three to be presumably valid species, and *E. khurodensis* to be a synonym of *E. auburnensis*.

***Eimeria bombayensis* Rao and Hiregaudar, 1954**

Description. Oocysts ellipsoidal, tending toward the cylindrical, sometimes with one side relatively flat and the other convex. Oocysts 32-40 by 20-25 μ with a mean of 37 by 22 μ . Micropyle distinct, 2-4 μ wide at base. Oocyst wall thickened around micropyle. Oocyst wall smooth, transparent, homogeneous, pale yellowish brown, 1.0-1.5 μ thick. Oocyst residuum absent. Presence or absence of oocyst polar granule not mentioned. Sporocysts 12-15 μ long, ovoid. Sporocyst residuum present. Sporozoites 4-6 μ long, rounded.

Sporulation Time. Two to 3 days according to Rao and Hiregaudar (1954).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bos indicus* (zebu).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Asia (India).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown. Rao and Hiregaudar (1954) stated that its prevalence was great in calves in a dairy herd near Bombay.

Remarks. Pellérdy (1965) considered this name a synonym of *E. auburnensis*, saying that it is apparently identical and differs from it in no essential characteristic. Bhatia et al. (1968) agreed. Patnaik (1965) considered it a synonym of *E. canadensis*. However, its sporocysts are smaller than those of *E. auburnensis* or *E. canadensis*. While we suspect that Pellérdy or Patnaik is probably correct, we prefer to list this name separately in case future research confirms that a difference exists.

Eimeria mundaragi Hiregaudar, 1956

Description. Oocysts ovoid, 36-38 by 25-28 μ , with a smooth, transparent, pale yellow or yellow wall 0.3 thick (slightly thicker at micropylar end). Micropyle distinct, 0.5 μ in diameter. Oocyst residuum and oocyst polar granule absent. Sporocysts ovoid, 15 by 9 μ , thinning at the pointed end. Sporocyst residuum present. Sporozoites 4-6 by 1-3 μ , finely granular (Hiregaudar, 1956).

Sporulation Time. One to 2 days during the summer according to Hiregaudar (1956).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bos indicus* (zebu).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. India (Bombay).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Levine (1961) remarked that the extremely thin wall and tiny, distinct micropyle might differentiate this form from other bovine coccidia, but that the possibility must not be overlooked that these oocysts might be those of another species from which the thick, brittle

outer wall had cracked. Patnaik (1965) considered this name to be a synonym of *E. auburnensis*, but *E. mundaragi*'s thin oocyst wall and lack of a polar granule appear to differentiate it. Bhatia et al. (1968) considered *E. mundaragi* to be a synonym of *E. bukidnonensis*; this is possible.

Eimeria sp. Rastegaieff, 1929

Eimeria smithi Yakimoff and Galouzo, 1927 of Rastegaieff, 1929b.

Rastegaieff (1929b, 1930) reported finding this species in 2 bison (*Bison bison*) in the Leningrad zoo. She called it "*Eimeria smithi* Yakimoff and Galouzo, 1927," but it is very unlikely that it actually belonged to this species (a synonym of *E. bovis*). The oocysts were ovoid, 16-29 by 14-21 μ , with a clearly visible micropyle 6 μ in diameter and an oocyst wall 1.8 μ thick. The sporocysts were piriform, 13.5 by 7 μ . Neither oocyst nor sporocyst residua were present. No oocyst polar granule was illustrated. The sporozoites were illustrated as lying lengthwise in the sporocysts.

Host Suborder RUMINANTIA

Host Superfamily BOVOIDEA

Host Family BOVIDAE

Host Subfamily HIPPOTRAGINAE

Host Tribe REDUNCINI

Eimeria macieli Yakimoff and Matchulski, 1938

(PLATE 10, FIG. 59)

Description. Oocysts ovoid, yellow, with a micropyle, flattened at the micropylar end, with a double-contoured, radially striated wall (illustrated as composed of a single layer) 1.5 μ thick. Oocysts 24-34 by 20-24 μ with a mean of 29.7 by 21.2 μ . Oocyst polar granule and residuum absent. Sporocysts described as ovoid, 10-14 by 4-6 μ , with a sporocyst residuum. Sporozoites elongate, lying lengthwise head to tail in sporocysts.

Sporulation Time. Ten days in 1% potassium bichromate solution at 15 C according to Yakimoff and Matchulski (1938).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Kobus* (syn., *Cobus*) *ellipsiprymnus* (waterbuck).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Leningrad zoo.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Host Suborder RUMINANTIA

Host Superfamily BOVOIDEA

Host Family BOVIDAE

Host Subfamily HIPPOTRAGINAE

Host Tribe ALCELAPHINI

***Eimeria talboti* Prasad and Narayan, 1963**

(PLATE 48, FIG. 196)

Description. Oocysts ovoid and asymmetrical, one side being slightly more convex than the other, 35-38 by 22-28 μ with a mean of 36 by 25 μ . Oocyst wall smooth, described as double-layered but illustrated with a single layer, yellowish. Micropyle absent. Oocyst residuum and polar granule absent. Sporocysts generally piriform, without Stieda body, 12.5-15 by 9-10 μ with a mean of 14 by 10 μ . Sporocyst residuum absent. Sporozoites spindle-shaped, lying lengthwise in sporocysts with both broad ends at the large end of the sporocyst, each with a large refractile globule at the rounded end.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Alcelaphus cokei* (syn., *A. cockei*) (harfebeest, kongoni).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Africa (Kenya).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

***Eimeria* sp. Prasad and Narayan, 1963**

Description. Oocysts ellipsoidal, 22-28 by 19-20 μ with a mean of 25 by 19 μ . Micropyle absent. Oocyst wall colorless, double-layered, with the outer layer slightly thicker than the inner one. Oocyst polar granule present. Oocyst residuum absent. Sporocysts lemon-shaped,

with a prominent Stieda body and a very thick wall, 11-12.5 by 6-7 μ with a mean of 11 by 6 μ . Sporocyst residuum not mentioned. Sporozoites with one end broadly rounded and the other sharply pointed.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Alcelaphus cokei* (syn., *A. cockei*) (hartebeest, kongoni).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Africa (Kenya).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Prasad and Narayan (1963) found only a few oocysts of the species and therefore hesitated to name it.

***Eimeria connochaetei* N. Sp.**

(PLATE 48, FIG. 197)

Eimeria ellipsoidalis Becker and Frye, 1929 of Prasad, 1960.

[non] *Eimeria ellipsoidalis* Becker and Frye, 1929.

Description. Oocysts roughly ellipsoidal, 20-27 by 13-15 μ with a mean of 22.1 by 14.0 μ . Oocyst wall smooth, pale yellow, with double membrane. Micropyle absent. Oocyst polar granule absent. Oocyst residuum absent. Sporocysts ovoid, with small (? not illustrated) Stieda body and sporocyst residuum. According to Prasad's text, the sporocysts were 4.5-5 by 2.5-3 μ ; however, either the oocysts were 22.1 by 14.5 μ and contained sporocysts 7.6-8.4 by 3.8-4.6 μ (oocyst dimensions from his text, and sporocyst dimensions calculated in relation to them from the figure) or the oocyst was 34 by 22 μ and contained sporocysts 12-13 by 6-7 μ (both oocyst and sporocyst dimensions calculated from his figure). Sporozoites 4.5-5 by 1.5 μ , lying lengthwise in sporocysts, with a clear globule at the large end.

Sporulation Time. According to Prasad (1960), complete sporulation took 48 hours at room temperature in 2.5% potassium bichromate solution.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Connochaetes gnu* (gnu, black wildebeest).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Tanganyika.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Prasad (1960) called this species *E. ellipsoidalis*, presumably because it resembled that species (from the ox). However, its sporocysts are smaller than those of *E. ellipsoidalis*, and the phylogenetic distance between the two hosts (*Bos* in the subfamily Bovinae and *Connochaetes* in the subfamily Hippotraginae) also suggests that it is a separate species.

***Eimeria gorgonis* Prasad, 1960**

(PLATE 50, FIG. 203)

Description. Oocysts ellipsoidal, 20.5-26 by 15-18 μ with a mean of 22.7 by 16.5 μ . Micropyle absent. Oocyst wall smooth, composed of 2 layers of which the outer is pale yellow and slightly thicker than the colorless inner layer. Oocyst polar granule very small; oocyst residuum absent. Sporocysts 12-15 by 4.5-6 μ , lemon-shaped with a distinct neck, a prominent Stieda body, a refractile vacuole at the narrow end, and a double membrane. Sporocyst residuum present. Sporozoites club-shaped, lying head to tail lengthwise in sporocysts, 10-13 by 3 μ , with a clear globule at the large end.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Gorgon taurinus* (brindled gnu, blue wildebeest).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. London zoo (from East Africa).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Host Suborder RUMINANTIA

Host Superfamily BOVOIDEA

Host Family BOVIDAE

Host Subfamily ANTILOPINAE

Host Tribe ANTILOPINI

***Eimeria antilocervi* Ray and Mandal, 1960 emend.**

Eimeria antilocervi Ray and Mandal, 1960.

Description. Oocysts cylindrical, 28-34 by 12-16 μ . Oocyst wall 1.5-2.0 μ thick, light brown, presumably composed of a single layer. Micropyle present, 1.5 μ wide. Oocyst polar granule not mentioned. Oocyst residuum absent. Sporocysts piriform, 11 by 7 μ . Sporocyst residuum present.

Sporulation Time. According to Ray and Mandal (1960), sporulation took 40-72 hours at 31 C in 2.5% potassium bichromate solution.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. Presumably *Antilope cervicapra* (antelope) (Ray and Mandal, 1960, called the host "*Antelope cervi caprae*.")

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. India (Calcutta Zoo).

Pathogenicity. Unknown.

Cross-Transmission Studies. Ray and Mandal (1960) were unable to transmit this species to a young calf (presumably a zebu calf).

Prevalence. Unknown.

***Eimeria impalae* Prasad, and Narayan, 1963**

(PLATE 50, FIGS. 205 and 206)

Description. Oocysts ellipsoidal, 30-36 by 20-24 μ with a mean of 33 by 22 μ . Oocyst wall described as double-layered but illustrated as composed of a single layer, smooth, yellowish green, with the inner layer slightly thicker than the outer one. Micropyle 6 μ wide, covered with "a thickening of the outer wall like that of *Eimeria stiedae* of the rabbit." Oocyst residuum and polar granules absent. Sporocysts ovoid, with one end broadly rounded 8-14 by 7-9 μ with a mean of 11 by 8 μ . Stieda body described as not prominent but not illustrated. Sporocyst residuum absent. Sporozoites spindle-shaped, 8-11 by 2-4 μ with a mean of 10 by 3 μ , with a refractile globule at the broader, rounded end.

Bigalke (1964) described a coccidium from the impala in South Africa which he said was *E. impalae*. Since there is a question whether he was dealing with this species, it is described separately here. Oocysts relatively robust, 33-45 by 22.5-31 μ with a mean of 39 by 27 μ . Oocysts ellipsoidal with the micropylar end slightly flattened and more

tapered than the opposite end. Micropyle formed by a thinning of the oocyst wall, about $6\ \mu$ in diameter. Oocyst wall yellowish brown, about $2\ \mu$ thick; number of layers not stated but illustrated with a single layer having a heavy inner line. Oocyst residuum and oocyst polar granule absent. Sporocysts elongate ovoid, with inconspicuous Stieda body, $18\text{--}21$ by $7.5\text{--}9\ \mu$. Sporocyst residuum composed of rather loosely scattered granules which obscured the sporozoites. Sporozoites elongate, presumably lying lengthwise in sporocysts, presumably with one large clear globule at one end and 1 or 2 smaller ones elsewhere (Bigalke could not distinguish the sporozoites with certainty).

Sporulation Time. Unknown.

Schizogony and Gametogony. Prasad and Narayan (1963) did not describe the endogenous stages. Bigalke (1964) saw no structures identifiable as schizonts, but found numerous gamonts, microgametes and oocysts in the small intestine and rarely the cecum and colon. The macrogametes were $9\text{--}10\ \mu$ in diameter when immature and grew to about 21 by $17\ \mu$ when mature. They had a layer of eosinophilic granules around their periphery. Their host cells were virtually obliterated, with only a compressed crescentic nucleus remaining; the parasites appeared to be distal to the nucleus. Both epithelial cells and histiocytes appeared to be parasitized. The microgamonts were present in the same location as the macrogametes. They were about $9\ \mu$ in diameter when young and grew to $30\text{--}48$ by $17.5\text{--}37.5\ \mu$ with a mean of 37 by $28\ \mu$. The microgametes developed in a number of nuclear whorls within the microgamonts, and became crescentic or filamentous and about $3\text{--}4\ \mu$ long when mature.

Prepatent Period. Unknown.

Type Host. *Aepyceros melampus* (impala).

Other Hosts. None.

Location. Oocysts found by Prasad and Narayan (1963) in feces. Endogenous stages found by Bigalke (1964) and Pienaar et al. (1964) in the small intestine (posterior third of jejunum and ileum) and rarely in the cecum and colon.

Geographic Distribution. Africa (Kenya, South Africa).

Pathogenicity. Prasad and Narayan (1963) found no evidence of pathogenicity, but Pienaar et al. (1964) and Bigalke (1966) considered this species highly pathogenic when young impala were brought together in small paddocks. Pienaar et al. described 3 outbreaks under these conditions in South Africa; in the first, 26 animals died, in the second 17 out of 27 animals, and in the third a single animal. The most prominent sign was diarrhea; there was no dysentery. Dehydra-

tion was also present. The intestine was virtually empty, and the mucosa of the posterior third of the jejunum and ileum was thickened and dull grayish-red, with numerous pinpoint- to pinhead-sized grayish foci scattered throughout. There were numerous intense red, irregular patchy areas from 1 cm in diameter to 7 cm long and involving the whole width of the gut. There was also a small number of subendo- and subepicardial petechiae. There was marked hyperemia of all layers of the intestine. The lamina propria and submucosa were slightly edematous. There did not appear to be definite cellular infiltration, although there may have been a slight increase in numbers of plasma cells and eosinophils in the propria.

The endogenous stages of the parasites (macrogametes, microgamonts, microgametes and oocysts) were mainly in the epithelial cells lining the crypts of Lieberkuehn. The infected glands were greatly enlarged, and the blood vessels in the heavily infected part of the intestine were markedly congested. Occasionally small groups of organisms (mostly oocysts) were found in the lymph nodes in the submucosa just below the muscularis mucosae; they were presumed to be in macrophages, but some were extracellular.

The lumina of many crypts contained erythrocytes and desquamated cellular debris.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. It is possible, as mentioned above, that the forms described by Prasad and Narayan (1963) and Bigalke (1964) may have belonged to different species, but for the present the evidence is not considered sufficient to justify their separation.

***Eimeria walleri* Prasad, 1960**

(PLATE 50, FIG. 204)

Description. Oocysts roughly oval, 27-30 by 22-25 μ with a mean of 28.5 by 23.5 μ . Micropyle distinct, about 3 μ wide. Oocyst wall smooth, colorless, with a triple membrane. Oocyst polar granule and oocyst residuum absent. Sporocysts broadly ovoid with a wall composed of a double membrane, 8-11 by 5-6 μ (as stated by Prasad, 1960) or either 10-11 by 6.5 or 12-13 by 7.6 μ (as determined by measuring his drawing). Stieda body present, very small. Sporocyst residuum present. Sporozoites roughly club-shaped, lying lengthwise head to tail in sporocysts, with a clear globule at the large end.

Sporulation Time. According to Prasad (1960), a few sporulated

oocysts were present at the end of the 5th day at room temperature in 2.5% potassium bichromate solution.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Litocranius walleri* (gerenuk).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. London Zoo.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

***Eimeria elegans* Yakimoff, and Gousseff and Rastegaieff, 1932**

(PLATE 50, FIG. 207)

Description. Oocysts elongate ovoid, almost cylindrical, with one end rounded and the other flattened, with a micropyle $3.6\ \mu$ wide. Oocyst wall composed of 2 layers. (Oocyst wall smooth, double contoured, yellow-green or yellow brown, and $1.1\text{--}1.8\ \mu$ thick according to Svanbaev, 1958.) Oocysts $23\text{--}45$ by $18\text{--}23\ \mu$ with a mean of 34.2 by $19.8\ \mu$ (37 by $20\ \mu$ according to Yakimoff and Machul'skiĭ, 1937b) ($32\text{--}39$ by $16\text{--}25\ \mu$ with a mean of 35.1 by $21.7\ \mu$ according to Svanbaev, 1958). Oocyst polar granule and residuum absent. (Polar granule sometimes present according to Svanbaev, 1958.) Sporocysts $10\text{--}14$ by $6\text{--}9\ \mu$ ($9\text{--}13$ by $7\text{--}11.5\ \mu$ with a mean of 10.7 by $8.8\ \mu$ according to Svanbaev, 1958). Sporocyst residuum present. Sporocysts ovoid, short-ovoid or spherical according to Svanbaev (1958). Sporozoites bean-shaped, comma-shaped or piriform, $6\text{--}9$ by $4\text{--}6\ \mu$ with a mean of 8 by $4.5\ \mu$ according to Svanbaev (1958). ($5\text{--}11$ by $2\text{--}4\ \mu$ according to Yakimoff and Machul'skiĭ, 1937b.)

Sporulation Time. Three to 5 days in 2% potassium bichromate solution at $25\text{--}28\text{ C}$ according to Svanbaev (1958); 7-8 days at 15 C according to Yakimoff and Machul'skiĭ (1937b).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Gazella subgutturosa* (goitered gazelle, zheiran, dscheiran).

Other Hosts. Svanbaev (1956) described *E. elegans* from the saiga *Saiga tatarica* in Kazakhstan. Oocysts ellipsoidal, $29\text{--}47$ by $17\text{--}26\ \mu$ with a mean of 37 by $20.5\ \mu$, colorless to greenish, yellow or lilac.

Oocyst wall smooth, double-contoured, 1.4-2.1 μ thick, with a micropyle at one end. Oocyst polar granule present, sometimes absent. Oocyst residuum absent. Sporocysts ovoid or spherical, 11-13 by 6.5-11 μ with a mean of 12 by 8 μ . Stieda body not mentioned. Sporocyst residuum present. Sporozoites bean-shaped, 7-8 by 5-6 μ , with a mean of 7 by 5 μ . Despite its resemblance to *E. elegans*, the fact that *Saiga* is in a different subfamily from *Gazella* makes us doubt whether the form described by Svanbaev is actually *E. elegans*.

Location. Oocysts found in feces.

Geographic Distribution. USSR (Turkestan, Kazakhstan).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Svanbaev (1958) found this species in 12% of 17 *G. subgutturosa* in Kazakhstan.

***Eimeria* spp. Ryšavý, 1954**

Eimeria arloingi Marotel, 1905 of Ryšavý, 1954 in *Gazella subgutturosa*.

Eimeria crandallis Honess, 1942 of Ryšavý, 1954 in *Gazella subgutturosa*.

Eimeria faurei Moussu and Marotel, 1901 of Ryšavý, 1954 in *Gazella subgutturosa*.

Eimeria niniae-kohl-yakimovi Yakimoff and Rastegaieva, 1930 of Ryšavý, 1954 in *Gazella subgutturosa*.

Description. None.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Gazella subgutturosa* (goitered gazelle).

Other Hosts. See Remarks.

Location. Oocysts found in feces.

Geographic Distribution. Czechoslovakia.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Ryšavý (1954) reported the above 4 species of *Eimeria* as occurring in *Gazella subgutturosa* in Czechoslovakia. The natural host of *E. arloingi* and *E. ninakohlyakimovae* is the domestic goat, and that of the others is the domestic sheep. Since Ryšavý did not describe any of them from the goitered gazelle, and since he attempted no cross-transmission experiments, it is impossible to give them names; it is

extremely doubtful that they actually belonged to the species to which he assigned them.

Eimeria sp. Svanbaev, 1958

Eimeria ninae kohl-jakimov Jakimoff and Rastegaieff, 1930 of Svanbaev, 1958.

Svanbaev (1958) gave the following information about "*E. ninae kohl-jakimov*" that he found in 41% of 17 gazelles *Gazella subgutturosa* in Kazakhstan: Oocysts oval, short-oval or spherical, 17-25 by 20-28 μ with a mean of 19.8 by 24.2 μ . Oocyst wall smooth, double contoured, greenish yellow green or brown, 1.2-1.7 μ thick. Micropyle absent. Sporocysts oval or short-oval, 5-8 by 6.5-11 μ with a mean of 8.7 by 6.4 μ . Sporozoites comma-shaped, 2-4 by 4-8 μ with a mean of 5.8 by 2.9 μ . Oocyst residuum absent. Sporocyst residuum present. Sporulation time 2-3 days in 2% potassium bichromate solution at 25-28 C.

Host Suborder RUMINANTIA

Host Superfamily BOVOIDEA

Host Family BOVIDAE

Host Subfamily CAPRINAE

Host Tribe SAIGINI

Eimeria sajanica Machul'skii 1947

Description. Since Machul'skii's (1947) paper is not available to us, we are using the information given by Svanbaev (1958). Oocysts ovoid or spherical, colorless, with a double-contoured wall up to 1.0 μ thick. Oocysts 18-23 by 16.5-20 μ with a mean of 20.7 by 18.3 μ . Oocyst polar granule and oocyst residuum absent. Sporocysts ovoid, 5-10 by 3-5 μ , with a sporocyst residuum.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Saiga tatarica* (saiga).

Other Hosts. None.

Location. Oocysts found in feces (?).

Geographic Distribution. USSR (Buryat-Mongolian ASSR).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Eimeria saiga Svanbaev, 1958

(PLATE 50, FIG. 208)

Description. Oocysts spherical, rarely short ovoid, 27-32 by 28-34 μ , with a mean of 29.5 by 30.5 μ . Oocyst wall smooth, double-contoured, yellowish green or yellowish brown, 1.0-1.4 μ thick, without micropyle. Polar granule usually present. Oocyst residuum present. Sporocysts spherical or short ovoid 7.5-12 by 7-9 μ with a mean of 10 by 8 μ . Sporocyst residuum present. Sporozoites spherical to ovoid, 3-5 by 4-6 μ with a mean of 4.2 by 4.9 μ .

Sporulation Time. Five to 7 days at 25-28 C in 2% potassium bichromate solution according to Svanbaev (1958, 1959).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Saiga tartarica* (saiga).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. USSR (Kazakhstan).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Svanbaev (1958) found this species in 2.5% of 163 saiga (3.8% of 26 animals 5-12 months old and 2.4% of 123 animals more than a year old) from western Kazakhstan and the Betpak-Dala Desert.

Host Suborder RUMINANTIA

Host Superfamily BOVOIDEA

Host Family BOVIDAE

Host Subfamily CAPRINAE

Host Tribe RUPICAPRINI

Eimeria rupicaprae Galli-Valerio, 1924

(PLATE 50, FIG. 209)

Description. According to Galli-Valerio (1924, 1927), the oocysts were ovoid, with a flattened end, a distinct micropyle, and measured 18-21 by 13-17 μ . The sporocysts were 6 by 3 μ , and the sporozoites comma-shaped and 1 by 0.8 μ . The oocysts assigned to this species by Yakimoff and Matschoulsky (1940) were ovoid, with a smooth yellowish double-contoured wall 1 μ thick and without a micropyle (but they illustrated it with one). They were 19-25 by 15-21 μ with a mean of 22.3 by 17.6 μ . An oocyst residuum was absent, and no oocyst polar

granule was illustrated. The sporocysts were ovoid 6-13 by 4-8 μ . A sporocyst residuum was present. Boch and Lucke (1961) found that the oocysts were 22-28 by 19-21 μ , with a micropyle and with a sporocyst residuum only. Kutzer (1964) said that the oocysts were 19-29 by 15-23 μ . Those measured by Restani (1968) were 21-32.5 by 16.5-27 μ with a mean of 32.5 by 20.5 μ , and the sporocysts averaged 12 by 7 μ .

Sporulation Time. Supperer and Kutzer (1961) said that the sporulation time was 4-6 days.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Rupicapra rupicapra* (chamois).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Austria, Germany, Italy, Leningrad Zoo, Switzerland).

Pathogenicity. Unknown.

Cross-Transmission Studies. Restani (1968) was unable to transmit this species to a goat, lamb and calf.

Prevalence. Unknown.

***Eimeria riedmuelleri* Yakimoff and Matschoulsky, 1940 emend.**

(PLATE 50, FIGS. 210 and 211)

Eimeria riedmülleri Yakimoff and Matschoulsky, 1940.

Description. Oocysts ovoid, ellipsoidal or spherical, with a double-contoured pale yellow wall 1-2 μ thick (somewhat thicker at the ends), illustrated with a wall composed of a single layer. Micropyle absent. Spherical oocysts 15-22 μ in diameter with a mean of 17.5 μ . Ovoid or ellipsoidal oocysts 19-23 by 15-19 μ with a mean of 20 by 17 μ according to Yakimoff and Matschoulsky (1940), 15-23 by 14.5-22 μ according to Supperer and Kutzer (1961), 15.5-22 by 14-20 μ according to Boch and Lucke (1961), 15-23 by 14-22 μ according to Kutzer (1964). Oocyst polar granule and oocyst residuum absent. Sporocysts ovoid to spherical, 6-13 by 6-8 μ , without sporocyst residuum, illustrated without Stieda body. Sporozoites illustrated as elongate, lying lengthwise head to tail in sporocysts, with a clear globule. The oocysts described by Restani (1968) were 16.5-23 by 15-20 μ with a mean of 20 by 17 μ ; the sporocysts averaged 8 by 6 μ .

Sporulation Time. Four to 6 days according to Supperer and Kutzer (1961).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Rupicapra rupicapra* (chamois).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Europe (Austria, Germany, Italy, Leningrad Zoo).

Pathogenicity. Unknown.

Cross-Transmission Studies. Restani (1968) was unable to transmit this species to a goat, a lamb or a calf.

Prevalence. Unknown.

***Eimeria yakimoffmatschoulskyi* Supperer and Kutzer, 1961 emend.**

(PLATE 50, FIG. 212; PLATE 61, FIG. 273)

Eimeria yakimoff-matschoulskyi Supperer and Kutzer, 1961.

Eimeria arloingi Marotel, 1905 of Yakimoff and Matschoulsky, 1940.

Eimeria böhmi Supperer, 1952 of Böhm and Supperer, 1956.

Description. Oocysts ellipsoidal or ovoid, with a wall 1.0-1.5 μ thick, yellowish, with a more or less distinct micropyle and colorless micropylar cap which is easily lost. Oocyst wall illustrated as composed of a single layer. Oocysts 24-32.5 by 18-22.5 μ (19.5-34 μ long) according to Boch and Lucke, 1961; 23-31 by 17-23 μ with a mean of 27.2 by 20.4 μ according to Yakimoff and Matschoulsky, 1940). Oocyst residuum absent. Oocyst polar granule absent. Sporocysts ovoid, 9.5-12.5 by 7-9 μ (8-12.5 by 6-8 μ according to Yakimoff and Matschoulsky, 1940), with sporocyst residuum. Sporocyst Stieda body not mentioned. The oocysts measured by Restani (1968) were 27-36.5 by 18-26 μ with a mean of 34 by 23.5 μ ; the sporocysts averaged 13 by 7 μ .

Sporulation Time. Three to 5 days according to Supperer and Kutzer (1961).

Prepatent Period. Unknown.

Type Host. *Rupicapra rupicapra* (chamois).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Europe (Austria, Germany, Italy, Lenin-grad Zoo).

Pathogenicity. Unknown.

Cross-Transmission Studies. Supperer and Kutzer (1961) were unable to transmit this species to the sheep or goat. Kutzer (1964) was unable to transmit it to 2 sheep. Restani (1968) said that he infected a goat and a lamb but not a calf with this species. The goat and lamb became positive 8 days after exposure. However, he gave no information on number of oocysts, and apparently made no pre-exposure examinations.

Prevalence. Unknown.

Remarks. Supperer and Kutzer (1961) said that this was the species previously reported from the chamois by Yakimoff and Matschoulsky (1940) as *E. arloingi* and by Böhm and Supperer (1956) as *E. böhmi*.

***Eimeria alpina* Supperer and Kutzer, 1961**

(PLATE 52, FIG. 217)

Description. The following description is based on Supperer and Kutzer (1961) and Kutzer (1964). Oocysts almost always spherical, 10-14 μ in diameter. Oocyst wall composed of one layer, very thin, colorless, smooth, without micropyle. Oocyst residuum and polar granule absent. Sporocysts subspherical, 5-6 by 4-5.5 μ , without sporocyst residuum. Sporozoites illustrated as elongate, lying head to tail in sporocysts.

Sporulation Time. Unknown.

Prepatent Period. Unknown.

Type Host. *Rupicapra rupicapra* (chamois).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Europe (Austria).

Pathogenicity. Unknown.

Cross-Transmission Studies. Kutzer (1964) was unable to transmit this species to 2 sheep.

Prevalence. Unknown.

***Eimeria suppereri* Kutzer, 1964**

(PLATE 52, FIG. 215)

Description. Oocysts ellipsoidal, generally 43-49 by 32-37 μ with a

mean of 45 by 34 μ . Oocyst wall composed of 2 layers, the outer one 1.5-2.0 μ thick, rough, brown, with a micropyle, and relatively difficult to separate from the inner layer, which is colorless to yellowish and about 1 μ thick. One or 2 oocyst polar granules present; oocyst residuum absent. Sporocysts drop-shaped, 16-19 by 9-11 μ , with sporocyst residuum.

Sporulation Time. Generally 12-14 days at 25 C in 1.5% potassium bichromate solution according to Kutzer (1964).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Rupicapra rupicapra* (chamois).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Austria).

Pathogenicity. Unknown.

Cross-Transmission Studies. Kutzer (1964) was unable to transmit this species to 2 sheep.

Prevalence. Unknown.

***Eimeria* spp. of Ryšavý, 1954 and of Delić and Čanković, 1961**

Eimeria arloingi Marotel, 1905 of Ryšavý, 1954 and of Delić and Čanković, 1961 in *Rupicapra rupicapra*.

Eimeria crandallis Honess, 1942 of Ryšavý, 1954 in *Rupicapra rupicapra*.

Eimeria ninae-kohl-yakimovi Yakimoff and Rastegaieva, 1930 of Ryšavý, 1954 and of Delić and Čanković, 1961 in *Rupicapra rupicapra*.

Eimeria parva Kotlan, Moezy and Vajda, 1929 of Ryšavý, 1954 in *Rupicapra rupicapra*.

Description. None.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Rupicapra rupicapra* (chamois).

Other Hosts. See Remarks.

Location. Oocysts in feces.

Geographic Distribution. Czechoslovakia, Yugoslavia.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Ryšavý (1954) reported the above 4 species of *Eimeria* as occurring in *Rupicapra rupicapra* in Czechoslovakia and Delić and Čanković (1961) reported *E. arloingi* and *E. ninakohlyakimovae* from the same host in Yugoslavia. The natural host of *E. arloingi* and *E. ninakohlyakimovae* is the domestic goat and that of the others is the domestic sheep. Since Ryšavý did not describe any of them from the chamois, and since he attempted no cross-transmission experiments, it is impossible to give them names; it is extremely doubtful that they actually belonged to the species to which he assigned them.

***Eimeria longispora* Rudovsky, 1922**

Description. Rudovsky (1922) reported finding this species in chamois feces in Austria. His complete description was, "Die eine Form wird wegen der Sporozoitengestalt *Eimeria longispora* benannt und ist neu." Obviously, this description is so incomplete that the form can never be recognized, and the name *Eimeria longispora* must be considered a nomen nudum.

Host. *Rupicapra rupicapra* (chamois).

Other Hosts. Pellérdy (1963, 1965) gave the domestic goat and domestic sheep as hosts, but we have not seen this species reported from these hosts.

Remarks. Pellérdy (1965) said that he had never read the original description of this species, but thought it advisable to invalidate it because "the few references in the literature to that description show it to be rather imperfect."

***Eimeria oreamni* Shah and Levine, 1964**

(PLATE 52, FIG. 216)

Description. Oocysts elongate ovoid, slightly piriform, 26-34 by 17-20 μ with a mean of 29 by 19 μ . Oocyst wall composed of 2 layers, the outer smooth, pale greenish-yellow to yellowish-brown, about 1 μ thick, the inner layer brownish-yellow, about 0.4 μ thick. Oocyst lined by a membrane apparently formed by the inner layer and usually slightly wrinkled at the micropylar end. Micropyle at small end of oocyst, about 2 μ wide. Micropylar cap absent. Oocyst polar granules present, fragmented. Oocyst residuum absent. Sporocysts broadly ovoid, with tiny Stieda body, 10-12 by 7-9 μ with a mean of 11 by 8 μ . Sporocyst residuum present, usually consisting of granules scattered

loosely in sporocyst. Sporozoites elongate, one end narrower than the other, lying lengthwise head to tail in sporocysts. A single large, clear globule at one end of sporozoite; sometimes one or more additional smaller clear globules present in each sporozoite.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Oreamnos americanus* (Rocky Mountain goat).

Other Hosts. None.

Location. Unknown. Oocysts found in feces.

Geographic Distribution. North America (Montana).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Todd and O'Gara (1968) also found this species in an *O. americanus* from Montana.

***Eimeria ernsti* Todd and O'Gara, 1968**

(PLATE 51, FIG. 213)

Eimeria ernsti Todd and O'Gara (1968). *Lapsus calami*.

Description. Oocysts ellipsoidal, sometimes with nearly flat sides, 28-37 by 19-25 μ with a mean of 33 by 23 μ . Oocyst wall smooth, composed of 2 layers and an inner membrane, 1.8-2.3 μ thick. Outer layer light brown, about $\frac{3}{4}$ of total wall thickness; inner layer dark brown. Inner membrane wrinkled in micropylar area. Micropyle present. Micropylar cap present, 7-11 μ wide and 2-4 μ high with a mean of 9 by 3 μ . Oocyst residuum absent. Oocyst polar granule present in freshly sporulated oocysts, rare in older oocysts. Sporocysts elongate ovoid, 14-20 by 6-9 μ with a mean of 17 by 7 μ . Stieda body distinct. Sporocyst residuum present. Sporozoites located at an angle near each end of sporocyst. Sporozoites with single large refractile wrinkled globule.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Oreamnos americanus* (Rocky Mountain goat).

Other Hosts. None.

Location. Unknown. Oocysts found in feces.

Geographic Distribution. North America (Montana).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Eimeria montanaensis Todd and O'Gara, 1968

(PLATE 51, FIG. 214)

Description. Oocysts subspherical to ellipsoidal, flattened at micropylar end, 15-23 by 13-19 μ with a mean of 19 by 15 μ . Oocyst wall smooth, composed of 2 layers about 1.5-2.0 μ thick; outer layer light blue, about $\frac{2}{3}$ of total wall thickness; inner layer light brown. Micropyle present, 2-3.5 μ wide. Small micropylar cap on 6% of oocysts. Oocyst residuum absent. Oocyst polar granule present, sometimes fragmented into as many as 5 pieces. Sporocysts broadly to elongate ovoid, 8-12 by 4-7 μ with a mean of 10 by 5 μ . Sporocyst residuum composed of a few fine granules between sporozoites. Stieda body small. Sporozoites blunt, located at an angle near each end of the sporocyst. A large and a small refractile globule present in each sporozoite.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Oreamnos americanus* (Rocky Mountain goat).

Other Hosts. None.

Location. Unknown. Oocysts found in feces.

Geographic Distribution. North America (Montana).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Host Suborder RUMINANTIA

Host Superfamily BOVOIDEA

Host Family BOVIDAE

Host Subfamily CAPRINAE

Host Tribe CAPRINI

Eimeria arloingi (Marotel, 1905) Martin, 1909

(PLATE 52, FIGS. 218-221; PLATE 53, FIGS. 222-223; PLATE 54, FIGS. 224-225)

Coccidium arloingi Marotel, 1905.

Eimeria ahsata Honess, 1942 of Chevalier (1966) from the goat, non *E. ahsata* Honess, 1942 of Chevalier (1965) from the sheep.

Eimeria crandallis Honess, 1942 of Chevalier (1966) from the goat.

Eimeria faurei (Moussu and Marotel, 1902) of Tsygankov, Païchuk and Balbaeva (1963) and of some other Russian authors.

Description. The following description is based on Levine, Ivens and Fritz (1962), Shah and Joshi (1963), Chevalier (1966) and Sayin (1965). Oocysts ellipsoidal or slightly ovoid, slightly flattened at the micropylar end, 22-36 by 16-26 μ with a mean of 28 by 19-21 μ . Oocyst wall composed of 2 layers, the outer one smooth, colorless, 1.0 μ thick, and the inner one brownish yellow, 0.4-0.5 μ thick. The inner layer forms a membrane which is often slightly wrinkled at the micropylar end. Micropyle present at small end of oocyst. Micropylar cap prominent, colorless, mound-shaped, 0.4-3.0 μ high and 4-9 μ wide with a mean of 2 by 6-7 μ . One or more oocyst polar granules ordinarily present; they sometimes appear to be shattered into many rather fine particles. Oocyst residuum absent. Sporocysts elongate ovoid, with a rather truncate small end. Stieda body absent or vestigial. Sporocysts 11-17 by 6-10 μ with a mean of 13-15 by 7-8 μ (10 by 5 μ according to Singh, 1964). Sporocyst residuum present. Sporozoites elongate, lying lengthwise, head to tail, in sporocysts. Sporozoites usually contain a large, clear globule at the large end and a small one at the small end.

Sporulation Time. Two to 4 days according to Chevalier (1966), 60 hours at 20 C according to Sayin (1965), or 1-2 days at room temperature in India (Singh, 1964).

Schizogony and Gametogony. Uncertain. Levine, Ivens and Fritz (1962) found 2 types of schizont in a kid infected with *E. arloingi*, *E. christensenii* and *E. crandallis*. It is possible (but not proven) that they may have been those of *E. arloingi*. Giant schizonts up to 280 by 150 μ were present in endothelial cells of lacteals in the jejunum. They were surrounded by 2 layers of eosinophilic material. They saw different developmental stages of these schizonts. Some contained a number of groups of nuclei arranged in circles, others contained nuclei quite evenly distributed through the whole schizont, and still others contained fully developed merozoites. These last were straight, with one end rounded, and tapered to a point at the other end. They were about 10-12 by 0.8-1.2 μ , with vesicular, ellipsoidal to spherical nuclei without an endosome, about 1.3-1.5 μ in diameter, and lay at the wider end of the merozoite with no cytoplasm discernible between them and the end of the cell. The merozoites lay side by side in clusters like bundles of sticks within the schizonts, with the nuclei of each cluster

all at the same end. Each giant schizont contained approximately 100,000 merozoites.

One collapsed giant schizont, which had released the great majority of its merozoites, was found in a lacteal. Most of the epithelial cells of the villi and glands in its vicinity contained merozoites which had apparently penetrated them only recently and which were in the process of rounding up. These merozoites lay above the host cell nuclei and were surrounded by a clear area about 3-5 μ in diameter. The rounded-up merozoites were about 3 μ in diameter and contained vesicular nuclei about 1 μ in diameter with a small, central endosome.

A second type of schizont was present in some glands of the jejunum. Large numbers of these small schizonts and of single merozoites lay rather deep in the glands of Lieberkuehn, where they occurred in groups. The mature small schizonts lay above the host cell nuclei of the epithelial cells, enlarging the host cell somewhat. They were about 10-14 by 9-10 μ with a mean of 12 by 9 μ and appeared to contain 16-22 merozoites each. The merozoites lay parallel to each other like a bundle of sticks. They were straight, elongate lanceolate, with one end rather bluntly rounded and the other drawn out more. They were about 9 by 0.8 μ and had a vesicular nucleus without a central endosome, about 2.2 by 1.0 μ which was about 1 μ or less from the large end of the merozoites.

There were numerous diffusely scattered pale yellow to white focal plaques about 0.5 cm in diameter in the mucosa of the duodenum, jejunum and ileum; a few were present in the first third of the colon. The plaques consisted essentially of masses of macrogametes, microgamonts and young oocysts in the epithelial cells of the tips and sides of the villi and also in the crypts. The parasites ordinarily lay above the host cell nuclei, and multiple infections of the same host cell were the rule. The mature macrogametes were 12-24 by 8-15 μ with a mean of 16 by 12 μ in stained sections. The mature microgamonts were 11-26 by 8-16 μ with a mean of 16 by 11.5 μ and contained crescentic or comma-shaped microgametes about 3.5 μ long and 0.4 μ wide. The young oocysts were 19-26 by 12-18 μ with a mean of 24 by 15 μ , and often had discernible micropylar caps.

Levine, Ivens and Fritz (1962) concluded that the giant schizonts which they described were probably those of *E. arloingi* and that the small schizonts and sexual stages were those of either *E. arloingi*, *E. crandallis*, *E. christensen*i or a fourth species which had not yet begun to produce oocysts in the feces. Sayin (1965) found giant schizonts up to 141 by 100 μ in endothelial cells of the lacteals in the villi of the ileum in Angora goats. He found no other schizonts. He found

gamonts and oocysts in the epithelial cells of the tips and sides of the villi and also in the crypts in the small intestine, where they formed pale yellow to white plaques 0.3-0.4 mm in diameter.

P. P. Singh and Pande (1967) and Pande et al. (1967) found endogenous stages in the small intestine of goats in India that they thought were those of *E. arloingi*. However, they were dealing with mixed infections.

Prepatent Period. Unknown.

Type Host. *Capra hircus* (domestic goat).

Other Hosts. *Capra aegagrus*, *C. falconeri* (see Ryšavý, 1954), *C. ibex* (see Couturier, 1962; Pellérdy, 1965), *C. sibirica* (called *E. faurei* by Svanbaev, 1958). See *Remarks* for reports from additional hosts.

Location. Small intestine.

Geographic Distribution. Worldwide.

Pathogenicity. Uncertain. Deiana and Delitala (1953b) reported that *E. arloingi* gamonts and gametocytes had caused hyperplasia of the small intestine with pseudo-adenomatous metaplasia of the villi, atrophy of the crypts of Lieberkuehn and cellular infiltration of the mucosa in kids. Gill and Katiyar (1961) described an outbreak of enteritis associated with lesions in the ileum in 12 kids 1-2 months old in India which they considered due to *E. arloingi*. Sharma Deorani (1966) also described lesions in the small intestine of 4 naturally infected goats in India which he considered due to *E. arloingi*; he did not describe the oocysts. The lesions in the small intestine seen by Levine, Ivens and Fritz (1962) in a kid in Illinois have been described above. However, in both cases it is uncertain whether the enteritis was caused by *E. arloingi* or by another coccidium. Sayin (1965) found white to pale yellow plaques 0.3-0.4 mm in diameter, with irregular edges in the small intestine of Angora goats in Turkey. The feces of one kid were watery.

Cross-Transmission Studies. Deiana and Delitala (1953a) attempted to transmit "*Eimeria arloingi*" (probably a mixture of several species of *Eimeria* with capped micropyles) from the goat to two 1-month-old lambs, two 1-month-old rabbits and two 40-day-old guinea pigs. They found a few oocysts in the lambs 4-10 days after exposure, but none in the rabbits and guinea pigs; they did not describe the oocysts they found, nor did they establish that the lambs were coccidia-free to begin with. Krylov (1961) was unable to transmit this species from the goat to 3 lambs 1.5 months old. Tsygankov, Paichuk and Balbaeva (1963) were unable to transmit *E. arloingi* (which they called *E. faurei*) from the goat to one saiga and one lamb, although they produced a patent infection in a kid. No other valid cross-transmission attempts have apparently been made.

Prevalence. Balozet (1932a) found this species in 56% of 41 goats in Tunisia. Jacob (1943) found it in 18% of 11 goats in Germany and Chevalier (1966) in at least 39% of 40 goats in the same country. Svanbaev (1957) found it in 52% of 48 goats in Kazakhstan. Sayin (1965, 1966) found this species in 77% of 900 Angora goats in Turkey. Wiesenhütter (1965) found it in 95% of 413 goats in Syria. Shah and Joshi (1963) found it in 31% of 300 goats in Madhya Pradesh, India. Singh (1964) found it in 84% of 214 goats, and Jha and Subramanian (1966) in 69% of 243 goats in Uttar Pradesh, India. Fernando (1957) found it in 43% of 62 goats in Ceylon.

Remarks. As stated under *E. ovina* below, the evidence indicates that the "*E. arloingi*" of sheep will not develop completely in the goat. In addition, Krylov (1961) and Tsygankov, Paichuk and Balbaeva (1963) were unable to transmit *E. arloingi* from the goat to sheep. Furthermore, there are certain structural differences between the oocysts of the 2 forms; the goat form is ellipsoidal while the sheep one generally has rather straight sides. For these reasons we think it best to consider the forms from these hosts to be different species, and to use the name *E. arloingi* for the goat form only.

Until it is proven otherwise, we feel it best not to consider as *E. arloingi* those coccidia reported by various authors from ruminants of genera other than *Capra*. These include *Ovis aries*, *O. canadensis*, *O. ammon*, *O. musimon*, the tahr *Hemitragus jemlahicus*, the chamois *Rupicapra rupicapra*, the red deer *Cervus elaphus*, the fallow deer *Dama dama*, the roe deer *Capreolus capreolus* and the gazelle *Gazella subgutturosa* (Jacob, 1943; Ryšavý, 1954; Svanbaev, 1958; Delić and Čanković, 1961; Pellérdy, 1965).

Chevalier (1966) reported as *E. ahsata*, *E. arloingi*, and *E. crandallis* forms which he found in the goat in Germany and which differed only in oocyst and sporocyst dimensions. These differences were not great, however; although they were statistically significant, the work of Becker et al. (1956) on *E. necatrix* of the chicken proved that statistically significant size differences occurred at different periods after an infection became patent. Hence, such variations in size cannot be justified as a basis for differentiating species. Consequently we consider that the above 3 "species" of Chevalier were actually *E. arloingi*.

Eimeria ninakohlyakimovae Yakimoff and Rastegaieff, 1930 emend. Levine, 1961

(PLATE 55, FIGS. 226-230)

Eimeria nina-kohl-yakimovi Yakimoff and Rastegaieff, 1930.

Eimeria galouzoi Yakimoff and Rastegaieff, 1930 *pro parte*.

Description. *E. ninakohlyakimovae* was first described by Yakimoff and Rastegaieff (1930) from the goat. The following description is based on those of the above authors and of Shah and Joshi (1963), Singh (1964), Sayin (1964) and Chevalier (1966) from the goat. Oocysts ellipsoidal or subspherical to somewhat ovoid, slightly narrow at the micropylar end, 19-28 by 14-23 μ . Oocyst wall composed of 2 layers, the outer one smooth, colorless to slightly yellowish and 1 μ thick, and the inner one yellowish-brown, 0.4 μ thick. Micropyle present at small end of oocyst (not reported by Yakimoff and Rastegaieff, 1930). Micropylar cap absent. Oocyst polar granule or granules present (Sayin, 1965, said that there was none). Oocyst residuum absent. Sporocysts elongate ovoid, 9-14 by 4-10 μ . Stieda body present. Sporocyst residuum present. Sporozoites elongate, lying lengthwise head to tail in sporocyst, with one or 2 clear globules.

The following description is based on those of Christensen (1938b), Shah (1963), Jackson (1964) and Chevalier (1965) from the sheep. Oocysts usually ellipsoidal or subspherical to somewhat ovoid, 16-30 by 13-22 μ with a mean of 23 by 18 μ (Christensen) or 26 by 20 μ (Shah; Jackson). Oocyst wall composed of 2 layers, the outer one smooth, colorless to slightly greenish yellow, 1 μ thick, the inner one yellowish brown, 0.4 μ thick; oocyst lined by a membrane often wrinkled at the micropylar end. Micropyle present at small end of oocyst. Micropylar cap absent. Two or more oocyst polar granules ordinarily present (Chevalier and Christensen saw none). Oocyst residuum absent. Sporocysts elongate ovoid, 10-14 by 4-8 μ with a mean of 12 by 7 μ (Shah) or 13 by 8 μ (Jackson). Stieda body present. Sporocyst residuum present. Sporozoites elongate, lying lengthwise head to tail in sporocysts. Sporozoites with one large and one small clear globule.

Sporulation Time. One-2 days according to Christensen (1938b), 3-4 days according to Balozet (1932a), 60 hours at 20 C according to Sayin (1964) or 1-3 days according to Singh (1964) and Chevalier (1965).

Schizogony and Gametogony. Balozet (1932a) and Sayin (1965) described the endogenous stages in the goat, and Lotze (1954) described them briefly from the sheep. Since their accounts differed, they are given separately below.

Balozet (1932b, c) found in a kid killed 39 days after infection that the schizonts were 15-35 μ in diameter and contained 40-200 merozoites 1.5-2 μ in diameter. The schizonts were in the epithelial cells of the glands of Lieberkuehn in the duodenum 3-4.5 meters from its

anterior end. The microgamonts were 45-50 μ in diameter, apparently in the same type of host cell. The microgametes were 3-4 μ long and had a flagellum 1-2 μ long. The macrogametes were apparently in the same type of host cell; Balozet did not give their size.

Sayin (1964) found one type of schizont in Angora goats. The schizonts were ellipsoidal or round, 31-43 by 22-31 μ with a mean of 37 by 26.5 μ ; they were in the epithelial cells of the ileum, cecum and upper part of the large intestine. Gamonts and oocysts were present in the same location. The mature macrogametes were 9-18 by 7-13 μ with a mean of 13.5 by 10 μ . The microgamonts were 20-25 by 15-18 μ with a mean of 22.5 by 16.5 μ and had whorls of microgametes on their surface and some residual material in the center.

Lotze (1954) found in sheep that the sporozoites entered the epithelial cells at the base of the glands of Lieberkuehn in the small intestine, where they formed schizonts about 300 μ in diameter containing thousands of merozoites. The macrogametes and microgamonts occurred in the epithelial cells of the ileum, cecum and upper part of the large intestine, appearing 15 or more days after infection.

Svanbaev (1967a) found that the patent period in 4 lambs was 8-10 days.

It is possible that Balozet, Sayin and Lotze were dealing with different species, or that Balozet and Sayin may have seen second generation merozoites not mentioned by Lotze.

N. Singh and Pande (1967) found endogenous stages in the small intestine of sheep in India that they thought were those of *E. ninakohlyakimovae*. However, they were dealing with mixed infections.

Prepatent Period. Balozet (1932b, c) found that the prepatent period was 10-13 days in goats; Shumard (1957a) found that it was 15 days in lambs, Krylov (1961) that it was 14 days in one lamb, Svanbaev (1967a) that it was 11-13 days in 4 lambs, and Hammond, Kuta and Miner (1967) that it was 9-10 days in most of 75 2.5-3.5-month-old lambs following inoculation of oocysts in dry or pelleted feed. The patent period was 10-28 days and peak oocyst production occurred 9-16 days after inoculation.

Type Host. *Capra hircus* (domestic goat).

Other Hosts. *Capra aegagrus* (wild goat), (Ryšavý, 1954); *C. sibirica* (Siberian wild goat) (Ryšavý, 1954; Svanbaev, 1958); *C. ibex* (Alpine ibex) (Couturier, 1962); *Ovis aries* (domestic sheep) (many authors); *O. canadensis* (bighorn sheep) (Honess, 1942); *O. musimon* (mouflon) (Yakimoff, Gousseff and Rastegaieff, 1932b; Ryšavý, 1954); *O. ammon* (argali) (Ryšavý, 1954; Svanbaev, 1958). In addition, Yakimoff and Matikaschwili (1933) reported this species from a

Gazella subgutturosa from Transcaucasia; Ryšavý (1954) reported it from *Capreolus capreolus*, *Cervus elaphus*, *Dama dama*, *Rupicapra rupicapra* and *Gazella subgutturosa*; Svanbaev (1958) reported it from *G. subgutturosa* and *Saiga tartarica* and Delić and Čanković (1961) from *R. rupicapra*. Whether this species actually occurs in hosts other than *Capra* and *Ovis* is doubtful.

Location. Small intestine, especially the posterior part, and also cecum and colon.

Geographic Distribution. Worldwide.

Pathogenicity. Balozet (1932a) observed a case of mucosanguinous diarrhea followed by death in a naturally affected adult goat, and produced the disease experimentally in 2 newborn kids. A mucous diarrhea appeared 22 days after infection, became bloody, and persisted until about the 39th day. Sayin (1964) found numerous round, smooth white plaques about 0.2-0.3 mm in diameter in the mucosa of the small intestine, cecum and colon. There was slight to moderate enteritis. The cellular reaction consisted of lymphocytes and polymorphonuclear leucocytes.

This is one of the most pathogenic of sheep coccidia. Svanbaev (1967b) observed clinical effects in 3 of 4 40-day-old lambs fed about 10,000 oocysts. Diarrhea, sometimes dysentery, fever, depression, inappetance, anemia, loss of weight, and loose wool were among the symptoms. Lotze (1954) found that as few as 50,000 oocysts caused diarrhea in a 3-month-old lamb; as few as 500,000 oocysts caused death. He produced dysentery in a 2-year-old sheep by inoculation with as few as 1 million oocysts. Smith and Davis (1965) found that only 20,000 oocysts caused death and only 10,000 caused clinical signs in lambs if the oocysts were given in dry feed rather than in liquid.

Lotze (1954) found that the feces of experimentally infected lambs became soft in 12-17 days. They became watery a day or two later and remained so for a week or more. The feces of the more heavily infected lambs contained blood-stained mucus beginning 15 days after infection or soon thereafter. The feces of those animals which recovered remained soft for some weeks.

Hammond, Kuta and Miner (1967) found in lambs 2.5-3.5 months old given oocysts in dry feed that 48,500 oocysts produced diarrhea lasting 3-11 (mean 7) days and dysentery lasting 3-10 (mean 6) days; 2 of 11 lambs died 16-21 days after inoculation. In lambs given 58,200 oocysts, the diarrhea lasted 5-9 (mean 6.6) days and the dysentery 0-4 (mean 1.4) days; no lambs died. In lambs given 97,000 oocysts, the diarrhea lasted 4-12 (mean 7) days and the dysentery 4-8 (mean 5.5) days; 6 of 10 lambs died 14-22 days after inoculation. In all groups

diarrhea began 10-11 days and dysentery 11-12 days after inoculation.

At necropsy, Lotze (1954) found petechial hemorrhages in the small intestine 3-7 days after infection. The small intestine then became thickened and inflamed. There was extensive hemorrhage in the posterior small intestine of severely affected lambs by the 15th day. The cecum and upper part of the large intestine became thickened and edematous, and were hemorrhagic by the 19th day. Vast areas of the posterior small intestine of heavily infected lambs were denuded. Svanbaev (1967a) noted similar lesions in the small intestine, and also saw white pinhead nodules in the jejunum and ileum.

Shumard (1957b) studied a less pathogenic strain. He observed lowered feed consumption, lassitude, generalized incoordination and slight diarrhea with some bleeding in 50-day-old lambs experimentally inoculated with 7 million oocysts of *E. ninakohlyakimovae* plus 100,000 oocysts of *E. faurei*. Clinical signs appeared 9 days after inoculation and ended about the 22nd day. One out of 4 lambs died on the 15th day.

Cross-Transmission Studies. Balozet (1932a) was unable to infect a recently weaned lamb with *E. ninakohlyakimovae* from a goat, although he did infect 2 newborn kids; he thought that the lamb was too old. Krylov (1961) failed to infect 2 yearling goats with *E. ninakohlyakimovae* from sheep, although he did infect a 2-month-old lamb. Lotze et al. (1961) failed to infect 6-month-old goats with *E. ninakohlyakimovae* from sheep or 4-month-old sheep with this species from the goat; at any rate, they found no oocysts in the feces. Lotze et al. (1964) found schizonts of an unknown coccidial species in the mesenteric lymph nodes of 2- and 7-month-old goats fed a mixture of 70% *E. arloingi*, 25% *E. ninakohlyakimovae* and 5% *E. faurei* oocysts from the sheep. Tsygankov, Paichuk and Balbaeva (1963) were unable to transmit *E. ninakohlyakimovae* from the sheep to one saiga and 4 kids, although they produced a patent infection in a lamb. They were unable to transmit *E. ninakohlyakimovae* from the goat to one saiga and one lamb although they produced a patent infection with it in a kid. Fitzsimmons (1964) infected 2 coccidia-free kids aged 50 and 58 days with *E. ninakohlyakimovae* from sheep; oocyst production was lower than in a control lamb. In an uncontrolled experiment, Subramanian and Jha (1966) said that they transmitted *E. ninakohlyakimovae* from the goat to a lamb by feeding it 50,000 oocysts.

In the absence of Fitzsimmons' and Subramanian and Jha's findings, it would be safe to say that the form in the sheep belongs to a different species from that in the goat. However, under the present circumstances, it appears that they may be different strains or demes of the

same species. Further work should be done to resolve this question.

Prevalence. Balozet (1932a) found this species in 34% of 41 domestic goats in Tunisia; Svanbaev (1957) in 31% of 48 goats in Kazakhstan; Chevalier (1966) in 12% of 40 goats in Germany; Merdivenci (1959) in 36% of the goats he examined in Turkey; and Sayin (1964, 1966) in 23% or 25% of 900 Angora goats in Turkey. Wiesenhütter (1965) found it in 56% of 642 sheep and 60% of 413 goats in Syria; Shah and Joshi (1963) in 12% of 300 goats in Madhya Pradesh, India; Singh (1964) in 23% of 214 goats and Jha and Subramanian (1966) in 53% of 243 goats in Uttar Pradesh, India.

Christensen (1938b) found it in 3% of 100 sheep from Maryland and Idaho; Hammond and Hamilton (1940, 1941) in 4% of 50 sheep in northern Utah; Shah (1963) in 1% of 153 sheep from Illinois and other states; Joyner et al. (1966) in 88% of 198 sheep in England; Jacob (1943) in 5% of 100 sheep in Germany; Chevalier (1965) in 26% of 200 sheep in Germany; Patyk (1965) in 26% of 222 lambs aged 1-8 months in Poland; Delić (1955) in 14% of the sheep and lambs he examined in Yugoslavia; Merdivenci (1959) in 13% of the sheep he examined in Turkey; Balozet (1932a) in 35% of 63 sheep in Tunisia; and Svanbaev (1957) in 52% of 302 sheep in Kazakhstan, USSR.

Remarks. The results of cross-transmission experiments described above bring into question whether sheep and goats both have *E. ninakohlyakimovae*. The oocysts reported under this name from hosts of other genera are probably not *E. ninakohlyakimovae*.

Eimeria christenseni Levine, Ivens and Fritz, 1962

(PLATE 55, FIG. 234)

Description. The following description is based on Levine, Ivens and Fritz (1962), Shah and Joshi (1963), Shah (1965) and Chevalier (1966). Oocysts ovoid, sometimes ellipsoidal, slightly flattened at micropylar end, 32-44 by 22-30 μ with a mean of 38-39 by 25-26 μ . Oocyst wall composed of 2 layers, the outer one smooth, colorless to very pale yellowish, about 1.0 μ thick, and the inner one brownish yellow, 0.4 μ thick. The inner layer forms a membrane which is usually wrinkled at the micropylar end. Micropyle present, at small end of oocyst. Micropylar cap prominent, colorless, mound-shaped, 1-4 μ high and 2-10 μ wide with a mean of 2-3 by 7-8 μ . One or more oocyst polar granules present, sometimes partly shattered into many rather fine particles. Oocyst residuum absent. Sporocysts broadly ovoid,

14-18 by 8-11 μ with a mean of 15-16 by 9-10 μ . Stieda body absent or vestigial. Sporocyst residuum present. Sporozoites lie lengthwise, head to tail, in sporocysts. Sporozoites contain a large, clear globule at one end and sometimes one or more additional smaller, clear globules.

Sporulation Time. Six days according to Chevalier (1966).

Schizogony and Gametogony. Unknown. See the discussion of *E. arloingi*.

Prepatent Period. Unknown.

Type Host. *Capra hircus* (domestic goat).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. United States (Illinois), Europe (Germany), India (Madhya Pradesh, Uttar Pradesh), Africa (Senegal).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Shah and Joshi (1963) and Shah (1965) found this species in 5% of 300 goats in Madhya Pradesh and Jha and Subramanian (1966) in 1% of 243 goats in Uttar Pradesh, India. Chevalier (1966) found it in 9% of 40 goats in Germany.

Remarks. This species has undoubtedly been confused with *E. ahsata* and *E. arloingi* in the past.

***Eimeria maroteli* Anon.**

Eimeria maroteli Anonymous; see Gill and Katiyar, 1961.

Description. No description was given.

Type Host. *Capra hircus* (domestic goat).

Geographic Distribution. India (Mukteswar).

Remarks. Gill and Katiyar (1961) said that a new species of coccidium which was named *E. maroteli* was found in the feces of a goat at Mukteswar, India, but that no description was given. This name was apparently given in the annual report of the Indian Veterinary Research Institute, Mukteswar, for 1949-50, and is obviously a *nomen nudum*.

***Eimeria ibicis* Colombo, 1958**

? *Eimeria faurei* Auctores in *Capra ibex*.

Description. Oocysts ovoid, bright rose, apparently smooth, with a

micropyle 5-6 μ wide, without micropylar cap, 27 by 18 μ , without oocyst residuum. No other information given.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Capra ibex ibex* (ibex).

Other Hosts. None.

Location. Oocysts found in feces.

Geographic Distribution. Italy.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Colombo (1958) found this species in the ibex in Gran Paradiso National Park, Italy. It is smaller than *E. faurei*, with which it might be confused, and has a broader micropyle.

***Eimeria faurei* (Moussu and Marotel, 1902) Martin, 1909**

(PLATE 55, FIGS. 231-233)

Coccidium faurei Moussu and Marotel, 1902.

Coccidium ovīs Jaeger, 1921 (according to Pellérdy, 1963):

? *Coccidium caprae* Jaeger, 1921 (according to Pellérdy, 1963).

Eimeria aemula Yakimoff, 1931.

Description. The following description of *E. faurei* from sheep is based on Balozet (1932a), Christensen (1938b), Kamalapur (1961) and Jackson (1964). Oocysts ovoid, with micropylar, narrow end slightly flattened. Oocysts 25-36 by 19-28 μ (25-33 by 18-24 μ with a mean of 29 by 21 μ according to Christensen, 1938a; 27-35 by 20-23 μ with a mean of 31.5 by 22 μ according to Balozet, 1932c; 27-30 by 18-28 μ with a mean of 28 by 23 μ according to Kamalapur, 1961; 28-37 by 21-27 μ with a mean of 32 by 23 μ according to Jackson, 1964). Oocyst wall smooth, composed of a single layer, faint green, greenish yellow, pale yellowish brown, delicate salmon pink, or pale yellowish pink, 1.3-1.8 μ thick, lined by a membrane. Micropyle conspicuous, 2-3 μ in diameter, described by Kamalapur (1961) as having a small internal plug. Micropylar cap absent. A small knob 1 μ high and 1-3 μ wide sometimes projects beyond the micropyle according to Kamalapur (1961). According to Jackson (1964), the micropyle is a prominent clear zone with a refractile cup-shaped inward projection. Oocysts polar granule present. Oocyst residuum absent. Sporocysts broadly ovoid, ovoid or piriform, 11-17 by 7-9 μ

with a mean of 14-15 by 8 μ . Stieda body absent or inconspicuous. Sporocyst residuum present, composed of many or scattered granules. Sporozoites lie lengthwise head to tail in sporocysts. One or two large globules present in each sporozoite.

The following description of *E. faurei* from the domestic goat is based on Shah and Joshi (1963) and Singh (1964). Oocysts ovoid, slightly flattened at narrower, micropylar end, 24-34 by 19-25 μ with a mean of 29-30 by 22 μ . Oocyst wall smooth, composed of a single layer, 1.4 μ thick, faint green to greenish yellow brown. Micropyle present, with a small internal plug. Micropylar cap absent. Oocyst polar granule present. Oocyst residuum absent. Sporocysts piriform, with one end pointed. Stieda body absent or vestigial. Sporocysts 11-17 by 8-11 μ with a mean of 13 by 9 μ . Sporocyst residuum present. Sporozoites lie lengthwise, head to tail, in sporocysts. Sporozoites usually with one or 2 large clear globules.

Svanbaev (1967a) said that the patent period was 9-10 days.

Sporulation Time. One to 2 days according to Christensen (1938b) and Singh (1964); 3-4 days according to Balozet (1932a).

Schizogony and Gametogony. The life cycle of *E. faurei* does not appear to have been worked out. According to Lotze (1953) its schizonts are about 100 μ in diameter and contain thousands of merozoites. N. Singh and Pande (1967) found endogenous stages in the large intestine of sheep and P. P. Singh and Pande (1967) in the large intestine of goats in India that they thought were those of *E. faurei*. However, they were dealing with mixed infections.

Prepatent Period. Twelve to 14 days according to Svanbaev (1967a).

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. *Ovis canadensis* (bighorn sheep), *O. ammon polii* (argali), *O. a. sewerzewi*, *O. musimon* (mouflon), *O. orientalis* (Asia Minor mouflon), *Ammotragus lervia* (audad, Barbary sheep), *Capra hircus* (domestic goat), *C. ibex* (ibex), *C. sibirica* (wild goat), *Rupicapra rupicapra* (chamois), *Capreolus capreolus* (roe deer), *Dama dama* (fallow deer) (Honess, 1942; Ryšavý, 1954; Donciu, 1961; Pellérdy, 1965). Whether this species actually occurs in hosts other than *Ovis* and *Capra* is dubious (see below).

Location. Small intestine.

Geographic Distribution. Worldwide.

Pathogenicity. *E. faurei* is only mildly pathogenic. Lotze (1954) found that single infections of 3-month-old lambs with 5 million oocysts produced only a temporary softening of the feces without significantly affecting the health or physical condition of the animals. Infections with 50 million oocysts failed to cause death. Svanbaev

(1967a) reported symptoms in 2 out of 4 40-day-old lambs given 10,000 oocysts each. They had diarrhea, inappetance, depression, anemia, conjunctivitis and gained weight poorly. Inflammation, hyperemia and gray-white nodules were present in the duodenum and rarely the jejunum and ileum.

Cross-Transmission Studies. Krylov (1961) was unable to transmit *E. faurei* from the sheep to the goat or from the goat to the sheep. Lotze et al. (1961) were unable to infect goats with *E. faurei* from sheep. Tsygankov, Pačhuk and Balbaeva (1963) were unable to transmit *E. faurei* (which they called *E. aemula*) from the sheep to one saiga and 4 kids, although they produced a patent infection in a lamb. They were unable to transmit *E. faurei* (which they called *E. aemula*) from the goat to one saiga and one lamb although they produced a patent infection with it in a kid. Fitzsimmons (1964), however, infected 2 coccidia-free kids 50 and 58 days old with *E. faurei* from sheep, but said that coccidia from sheep developed much better in sheep than in goats. In an uncontrolled experiment, Subramanian and Jha (1966) said that they transmitted *E. faurei* from the goat to a lamb by feeding it 160,000 sporulated oocysts.

Prevalence. Christensen (1938b) found *E. faurei* in 11% of 100 sheep from Idaho, Maryland, New York, and Wyoming; Hammond and Hamilton (1940, 1941) found it in 10% of 50 sheep in northern Utah; Shah (1963) in 6% of 153 sheep from Illinois and other states; Joyner et al. (1966) in 72% of 198 sheep in England; Jacob (1943) in 40% of 100 sheep in Germany; Chevalier (1965) in 4% of 183 sheep in Germany; Patyk (1965) in 33% of 222 lambs aged 1-8 months in Poland; Delić (1955) in 12% of the sheep and lambs he examined in Yugoslavia; Merdivenci (1959) in 13% of the sheep he examined in Turkey; Wiesenhütter (1965) in 23% of 642 sheep and 28% of 413 goats in Syria; Svanbaev (1957) in 43% of 302 sheep in Kazakhstan, USSR; Balozet (1932a) in 21% of 63 sheep in Tunisia and Deom and Mortelmans (1956) in 6% of 230 sheep in the Belgian Congo.

E. faurei has apparently not been found in goats in the United States. However, Jacob (1943) found it in 18% of 11 goats in Germany; Merdivenci (1959) in 17% of the goats he examined in Turkey; Svanbaev (1957) in 40% of 48 goats in Kazakhstan, USSR; Balozet (1932a) in 2% of 41 goats in Tunisia; Sayin (1966) in 5% of 900 Angora goats in Turkey; Shah and Joshi (1963) in 1% of 300 goats in Madhya Pradesh, India; Singh (1964) in 11% of 214 goats and Jha and Subramanian (1966) in 34% of 243 goats in Uttar Pradesh, India; and Fernando (1957) in 8% of 62 goats in Ceylon.

Remarks. Moussu and Marotel (1901) were the first to recognize

sheep coccidia as different from rabbit coccidia. They (1902) described them and named them *Coccidium faurei*. Martin (1909a) later transferred this species to the genus *Eimeria*. Later writers thought that sheep had one species of coccidium, which they called *E. faurei*, and that goats had another, which they called *E. arloingi*. Balozet (1932a), however, said that both species occurred in both sheep and goats, and Christensen (1938b) concurred. Subsequent authors have accepted their view. However, Orlov (1956), working in Kazakhstan (and also referring to the work of Melikyan, 1953, in Armenia) considered *E. arloingi* a synonym of *E. faurei*. He apparently based his opinion on work by Yakimoff (1931a) who held to the old view that all capped oocysts in sheep were those of *E. faurei*. Because of this view, Yakimoff (1931) had to give a new name, *E. aemula*, to the *E. faurei* that he saw in sheep. We now know that both sheep and goats have capped oocysts; their names are discussed elsewhere (*E. ahsata*, *E. arloingi*, *E. crandallis*, *E. christenseni*, *E. ovina*, *E. intricata*).

Whether both sheep and goats have *E. faurei* is open to question. Although the oocysts referred to this species from both hosts are apparently structurally identical, the fact that Krylov (1961), Tsyganov, Paichuk and Balbaeva (1963) and Lotze et al. (1961) failed to transmit them from one host to the other (although Fitzsimmons, 1964, did so) raises the question whether the forms from the 2 hosts may not be different strains or demes at the very least. Certainly, reports of *E. faurei* from hosts other than *Ovis* and *Capra* must be considered of dubious validity.

Eimeria intricata Spiegl, 1925

(PLATE 56, FIGS. 235-238; PLATE 61, FIG. 271)

Description. This species was described by Spiegl (1925), Balozet (1932a), Christensen (1938b), Ray (1961), Shah (1963), and Jackson (1964), among others. Oocysts ellipsoidal or slightly ovoid, 39-54 by 27-36 μ with a mean of 47 by 32 μ (Christensen), 46 by 33 μ (Spiegl) or 47-59 by 34-47 μ with a mean of 51 by 39 μ (Shah). Oocyst wall composed of 2 layers, the outer irregular, granular, brownish yellow to dark brown, 2-3 μ thick, transversely striated and appearing divided into 2 sublayers by a faint line; the inner layer dark brown, 0.4-0.8 μ thick; oocyst wall lined by a membrane which is often wrinkled at the micropylar end. Micropyle present, 6-10 μ in diameter and not extending to the inner layer. Micropylar cap prominent, dome-shaped, colorless to greenish yellow, 1-4 μ high and 6-18 μ wide;

micropylar cap detachable; Shah (1963) found none on 8 of 50 oocysts. One or more oocyst polar granules generally present. Oocyst residuum absent. Sporocysts elongate ovoid, with one end bluntly pointed, 17-22 by 9-14 μ with a mean of 20 by 11 μ (Shah) or 20 by 14 μ (Jackson). Stieda body absent or extremely tiny. Sporocyst residuum present. Sporozoites elongate, with one end narrower than the other, lying lengthwise head to tail in sporocysts, with 2-3 clear globules.

Sporulation Time. Three to 5 days at room temperature (Christensen, 1938b); 9-12 days at 21-23 C (Ray, 1961) or 4-6 days at room temperature (Singh, 1964).

Schizogony and Gametogony. Davis and Bowman (1965) and Pande, Bhatia and Chauhan (1966) studied the endogenous stages of this species. According to Davis and Bowman, the schizonts occur in the lower small intestine, mostly in the cells lining the intestinal crypts. The largest they found were only 65 by 45 μ and contained large merozoites up to 19.5 by 4 μ ; the size of the merozoites gave the schizonts a granular appearance. In one lamb killed 23 days after infection, gamonts and oocysts were found from midway in the small intestine posteriorly to the rectum, with most in the cecum. These forms, too, were in the cells lining the intestinal crypts. Pande, Bhatia and Chauhan (1966) found 4 mature schizonts in epithelial cells of the crypts; they were 32-37 by 21-25 μ with a mean of 34.4 by 22.7 μ and contained 25-40 spindle-shaped merozoites 7-9 by "2.5-2" μ . They found gamonts and oocysts in the epithelial cells of the crypts of the small intestine from the jejunum to the ileum. The oocysts in sections were 36-46 by 25-37 μ with a mean of 41 by 30 μ ; the macrogametes were 36-54 by 25-36 μ with a mean of 42 by 30 μ ; the fully developed microgamonts were 61-250 by 36-71 μ with a mean of 113 by 52 μ . The slender flagellated microgametes were 4.6-6 μ long. According to Davis and Bowman (1965) the patent period is 6-11 days; according to Svanbaev (1967) it is 5-6 days.

Prepatent Period. Twenty to 27 days according to Davis and Bowman (1965); 23 days according to Krylov (1961); 22-23 days according to Svanbaev (1967a).

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. *Ovis canadensis* (Rocky Mountain bighorn sheep) (Honess, 1942); *O. musimon* (mouflon) (Yakimoff, Gousseff and Rastegaieff, 1932a; Ryšavý, 1954); *O. ammon* (argali) (Svanbaev, 1958); *Capra hircus* (domestic goat) (Yakimoff, 1933a; Ray, 1961; Jha and Subramanian, 1966). In addition, Wetzell and Enigk (1936) reported it from the roe deer *Capreolus capreolus*, and Ryšavý (1954)

from this host and *Dama dama*; whether this species actually occurs in deer is doubtful.

Location. Davis and Bowman (1965) found the schizonts in the lower small intestine. They found gamonts and oocysts from midway in the small intestine posteriorly to the rectum, with most in the cecum. Pande, Bhatia and Chauhan (1966) found gamonts and oocysts in the jejunum and ileum. Both schizonts, gamonts and oocysts were in epithelial cells lining the crypts.

Geographic Distribution. Worldwide.

Pathogenicity. These oocysts are rarely found in large numbers. Svanbaev (1967a), who produced infections with 10,000 oocysts in 3 out of 4 40-day-old lambs that he exposed, observed clinical signs in 2 of them. These consisted of soft, mucoid feces, anemia, poor appetites, disinclination to move, a slight temperature and decreased weight gains. In one lamb which he killed 30 days after inoculation, he saw petechiae and an edematous mucosa in the jejunum and ileum (and slightly in the cecum); the lamb was no longer shedding oocysts at this time.

Cross-Transmission Studies. Krylov (1961) failed to transmit *E. intricata* from the sheep to 7 goats 3 months to 2 years old, but did succeed in infecting 2 lambs 1.5-2 months old. Lotze et al. (1961) failed to infect 6-month-old goats with *E. intricata* from sheep. Tsygankov, Païchuk and Balbaeva (1963) were unable to transmit *E. intricata* from the sheep to one saiga and 4 kids, although they produced a patent infection in a lamb.

Prevalence. Christensen (1938a) found this species in 14% of 100 sheep from Maryland, New York, and Wyoming; Hammond and Hamilton (1940, 1941) found it in 28% of 50 sheep in northern Utah; Shah (1963) found it in 7% of 153 sheep from Illinois and other states; Jacob (1943) in 13% of 100 sheep in Germany; Chevalier (1965) in 0.4% of 200 sheep in Germany; Joyner et al. (1966) in 29% of 198 sheep in England; Delië (1955) in 8% of the sheep and lambs he examined in Yugoslavia; Patyk (1965) in 7% of 222 lambs aged 1-8 months in Poland; Merdivenci (1959) in 5% of the sheep he examined in Turkey; Wiesenhütter (1965) in 19% of 642 sheep and none of 413 goats in Syria; Balozet (1932a) in 3% of 63 sheep in Tunisia; Svanbaev (1957) in 4% of 302 sheep in Kazakhstan, USSR; Singh (1964) in 1% of 214 goats; and Jha and Subramanian (1966) in 0.7% of 243 goats in Uttar Pradesh, India.

Remarks. The failure of Krylov (1961), Lotze et al. (1961) and Tsygankov, Païchuk and Balbaeva (1963) to infect goats with *E.*

intricata from sheep raises the question whether the same species occurs in both hosts. However, until careful comparative morphologic and life cycle studies are done, we are leaving the two forms as a single species.

Eimeria parva Kotlán, Mócsy and Vajda, 1929

(PLATE 56, FIGS. 239-241; PLATE 57, FIGS. 242-244)

Eimeria nana Yakimoff, 1933.

Eimeria galouzoi Yakimoff and Rastegaieff, 1930, *pro parte*.

Description. The forms in the sheep and goat are described separately. That in the sheep is based on Kotlán, Mócsy and Vajda (1929), Balozet (1932a), Svanbaev (1957), Christensen (1938b), Kamalapur (1961), Jackson (1964), and Chevalier (1965). That in the goat is based on Shah and Joshi (1963), Singh (1964) and Chevalier (1966).

Oocysts in the sheep subspherical, ovoid, ellipsoidal or spherical, slightly narrow at micropylar end, 12-23 by 10-19 μ with a mean of 16.5 by 14 μ (Christensen), 17 by 13.5 μ (Balozet), 18 by 15 μ (Kamalapur, Jackson) or 15 by 14.5 μ (Svanbaev). Micropyle inconspicuous. Micropylar cap absent. Oocyst wall smooth, pale yellow to yellowish green, brownish yellow or faint pinky mauve, composed of 2 layers, the outer 0.8-1.2 μ thick and thinning at the micropylar end, and the inner layer a dark, thin membrane. Oocyst polar granule generally present. Oocyst residuum absent. Sporocysts ovoid to elongate ovoid, 6-13 by 5-8 μ with a mean of 10 by 6 μ (Kamalapur) or 9 by 5 μ (Jackson). Stieda body absent or small. Sporocyst residuum present as a few fine granules. Sporozoites with one clear globule.

Oocysts in the Rocky Mountain bighorn sheep similar to those in the sheep but larger, 17.5-23.5 by 17-22 μ with a mean of 20 by 19 μ (Honess, 1942).

Oocysts in the goat 16-23 by 13-22 μ with a mean of 20 by 19 μ (Shah and Joshi), 14-19 by 12-15 μ with a mean of 16 by 13 μ (Singh), or 17 by 14.5 μ (Chevalier). Oocysts subspherical, ovoid to ellipsoidal or spherical. Oocyst wall smooth, pale yellow to yellowish brown or bright brown, composed of 2 layers, the outer 0.8 μ thick and the inner a dark thin membrane. Micropyle inconspicuous. Micropylar cap absent. Oocyst polar granule present (absent according to Chevalier). Oocyst residuum absent. Sporocysts broadly ovoid, 7-13 by 5-9 μ with a mean of 10 by 7 μ (Shah and Joshi) or 9 by 6 μ (Chevalier). Stieda body absent (present according to Singh). Sporocyst residuum

present (a small residuum present in only a very small number of sporocysts according to Chevalier). Sporozoites lie head to tail in sporocysts; each contains 2 clear globules.

Sporulation Time. One to 2 days (Christensen, 1938b; Singh, 1964), 7-8 days (Balozet, 1932a), 3-5 days in the sheep (Chevalier, 1965) or 2-5 days in the goat (Chevalier, 1966).

Schizogony and Gametogony. Kotlán, Pellérdy and Versényi (1951a, 1951b) described the endogenous stages in sheep. However, since Pellérdy (1965) considered *E. pallida* a synonym of *E. parva*, since at least one of their lambs was also infected with *E. ovina* and *E. intricata*, and since they found two types of schizont, it is not certain whether they were actually dealing with *E. parva* alone. They found schizonts throughout the small intestine that were up to 185-256 by 128-179 μ and easily visible to the naked eye as whitish bodies. They lay in the mucosa, usually near the surface but sometimes as far down as the muscularis mucosae. They invaded endothelial cells and enlarged both the host cell and its nucleus enormously. They were surrounded by a rather thick layer of connective tissue which became thinner as they increased in size. Each schizont produced thousands of straight merozoites 10-12 μ long.

A second, much smaller, type of schizont was also present in the small intestine. It occurred in the superficial epithelial cells, was 10-12 μ in diameter, and contained about 10-20 merozoites 2.5-3.0 μ long. Kotlán, Pellérdy and Versényi were not sure whether these were part of the life cycle of *E. parva*.

The sexual stages occurred mostly in the cecum and colon, and to a lesser extent in the small intestine. They were present in epithelial cells and were 15-19 by 10-16 μ .

N. Singh and Pande (1967) found endogenous stages in the large intestine of sheep in India that they thought were those of *E. parva*. However, they were dealing with mixed infections.

In 4 kids that died 11-15 days after inoculation with 25,000-250,000 sporulated oocysts, Sayin (1966) found gamonts and oocysts in mucosal scrapings from the colon, cecum and posterior small intestine, and schizonts in the epithelial cells of the villi of the middle part of the small intestine. The schizonts were up to 260 by 180 μ and could be easily seen with the naked eye as whitish bodies. He also saw much smaller schizonts 15-18 by 9-12 μ in the epithelial cells of the crypts of Lieberkuehn in one kid. The gamonts and oocysts were in the epithelial cells of the mucosa. The macrogametes were 14-18 by 9-14 μ and the microgamonts were 22-25 by 15-20 μ .

If the above accounts are accurate, then the forms known as *E. parva* in the sheep and goat are different species.

Svanbaev (1967a) found that the patent period in sheep was 6-8 days.

Prepatent Period. Fifteen days according to Krylov (1961), 11-13 days according to Svanbaev (1967a), 10-13 days according to Sayin (1966).

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. *Ovis orientalis* (mouflon), *O. ammon* (argali), *O. musimon* (mouflon), *O. canadensis* (bighorn sheep), *Capra hircus* (domestic goat), *C. sibirica* (Asian wild goat), *C. ibex* (Alpine ibex) (See Couturier, 1962). In addition, Yakimoff (1933b) reported this species from *Ammotragus lervia* (syn., *Ovis tragelaphus*) (aoudad), Jacob (1943) from a roe deer and Ryšavý (1954) from *Cervus elaphus* (red deer), *Capreolus capreolus* (roe deer), *Dama dama* (fallow deer) and *Rupicapra rupicapra* (chamois); however, these reports are erroneous (Pellérdy, 1965) or dubious. Indeed, it is uncertain whether this same species occurs in both *Ovis* and *Capra*.

Location. The schizonts occur in the small intestine, and the sexual stages mostly in the cecum and colon, and to a lesser extent in the small intestine. Svanbaev (1967a) said that *E. parva* is located in the duodenum and jejunum.

Geographic Distribution. Worldwide.

Pathogenicity. *E. parva* is apparently not very pathogenic in sheep. Most of the damage is caused by the sexual stages in the large and small intestines. In a lamb killed by Kotlán, Pellérdy and Versényi (1951b) 16 days after experimental inoculation, the contents of the cecum and colon were semifluid, dark and mixed with blood in places. The wall was thickened and its surface uneven and denuded of epithelium in places. On histologic examination, the cecal mucosa was found to have been stripped from the glandular layer in places, and the tissue had become necrotic and infiltrated with lymphocytes and neutrophils but no eosinophils. Sharply separated from these necrotic areas were other areas in which most of the epithelial cells contained microgamonts, macrogametes or young oocysts. Svanbaev (1967a) infected 3 out of 4 40-day-old lambs by feeding them 10,000 oocysts each. The coccidia produced no symptoms.

According to Sayin (1966), *E. parva* may be markedly pathogenic for the goat. Nine of 12 Angora goats 6-10 weeks old given 25,000-1 million oocysts developed diarrhea, and 4 of them died 11-15 days after inoculation. Four of the survivors were challenged 6 weeks

after inoculation with 5 or 10 million oocysts; none had clinical signs, and all discharged markedly fewer oocysts than after the original infection.

Cross-Transmission Studies. Krylov (1961) was unable to transmit *E. parva* from the sheep to 8 goats aged 3 months to 2 years, although he did infect 2 young lambs. Tsygankov, Paichuk and Balbaeva (1963) were unable to transmit *E. parva* (which they called *E. galouzoï*) from the sheep to one saiga and 4 kids, although they produced a patent infection in a lamb. They were unable to transmit *E. parva* (which they called *E. galouzoï*) from the goat to one saiga and one lamb although they produced a patent infection with it in a kid. Fitzsimmons (1964) was unable to infect two coccidia-free kids 50 and 58 days old with "*Eimeria pallida*/*Eimeria parva*" and other species from sheep. He did infect a control, coccidia-free lamb with these species, although they constituted only 1% of the coccidia passed by it.

Prevalence. Christensen (1938b) found this species in 50% of 100 sheep from Idaho, Maryland, and Wyoming; Hammond and Hamilton (1940, 1941) in 34% of 50 sheep in northern Utah; Shah (1963) in 5% of 153 sheep from Illinois and other states; Joyner et al. (1966) in 56% of 198 sheep in England; Jacob (1943) in 52% of 100 sheep in Germany; Chevalier (1965) in 7% of 200 sheep in Germany; Patyk (1965) in 52% of 222 lambs aged 1-8 months in Poland; Merdivenci (1959) in 31% of the sheep he examined in Turkey; Svanbaev (1957) in 9% of 302 sheep in Kazakhstan; Balozet (1932a) in 21% of 63 sheep in Tunisia; and Deom and Mortelmans (1956) in 41% of 230 sheep in the Belgian Congo.

Jacob (1943) found it in 9% of 11 goats in Germany; Chevalier (1966) in 2% of 40 goats in Germany; Merdivenci (1959) in 45% of the goats he examined in Turkey; Wiesenhütter (1965) in 38% of 642 sheep and 31% of 413 goats in Syria; Balozet (1932a) in 22% of 41 goats in Tunisia; Sayin (1966) in 26% of 900 Angora goats in Turkey; Deom and Mortelmans (1956) in 50% of 6 goats in the Belgian Congo; Shah and Joshi (1963) in 1.3% of 300 goats in Madhya Pradesh, India; Singh (1964) in 16% of 214 goats and Jha and Subramanian (1966) in 58% of 243 goats in Uttar Pradesh, India; and Fernando (1957) in 54% of 62 goats in Ceylon.

Remarks. In view of the failure of cross-transmission attempts of this species between sheep and goats, it is quite likely that the forms from these hosts actually belong to different species. However, in the absence of careful comparative structural and life cycle studies, we are retaining the name *E. parva* for both forms for the present.

Eimeria gilruthi (Chatton, 1910) Reichenow and Carini, 1937

Gastrocystis gilruthi Chatton, 1910.

Globidium gilruthi (Chatton, 1910) Nöller, 1920.

Description. The oocysts of this species are unknown, only the schizonts and merozoites having been seen (see below).

Sporulation Time. Unknown.

Schizogony and Gametogony. The schizonts occur in the connective tissue and mucous membranes of the abomasal wall. They are easily visible to the naked eye as whitish nodules, and are 300-900 μ in diameter. The cyst wall is up to 40 μ thick. The host cell nucleus is flattened and greatly enlarged. The mature schizonts contain thousands of crescent- to sickle-shaped merozoites about 4.5-7.5 μ long and 1.2-2.0 μ wide.

Gilruth (1910) said that the cyst in sheep was somewhat oval, 500 by 300 μ , and contained spindle-shaped merozoites, "with extremities tapering to a fine point," 4-6 by 0.5 μ , and with a central nucleus. Triffitt (1925) said that the cyst in sheep was rounded or ovoid, 300-900 μ in diameter, with a wall the inner layer of which was 36 μ thick in young cysts and 7.5 μ thick in almost mature cysts. This layer was dark grayish and composed of delicate, circumferentially arranged fibers in a very finely granular matrix. It composed about $\frac{1}{4}$ of the whole thickness of the young cysts and about $\frac{1}{3}$ of that of the mature cysts. Outside it was a lighter layer, coarsely granular on its inner surface and with a hyaline outer surface thrown up into slight folds and ridges so that it had a peculiar brushlike structure. In young cysts, the brushlike portion consisted of short, hairlike processes about 18 μ long; in old cysts it was markedly thinner, appearing only as a fine line. According to Triffitt (1925), the merozoites were elongate, slightly curved, rounded at one end and slightly tapering at the other, about 12 μ long and 2.5 μ wide, with a nucleus near the rounded end. Sarwar (1951) found it commonly in sheep and goats in Lahore, Pakistan. Bhatia and Pande (1966a) said that the mature schizonts in sheep were 677-878 by 584-830 μ and contained "millions" of merozoites of differing size and structure. They described 3 types. The largest were 13-15 by 1.6-1.8 μ with a mean of 14.0 by 1.7 μ ; they were somewhat sickle-shaped, with pointed ends and a vesicular or oval nucleus quite near one end. The intermediate-sized merozoites were 8-12 by 1.3-1.6 μ with a mean of 10.0 by 1.4 μ ; they were slightly slender, with one end blunt and the other tapering, and with an ovoid nucleus somewhat nearer the blunt than the tapering end. The smallest

merozoites were 7-8 by 1.3-1.7 μ with a mean of 7.0 by 1.5 μ ; they were spindle-shaped, with one end more pointed than the other, and with a vesicular nucleus near the center. Matta and Pande (1966) confirmed these findings.

Pande and Bhatia (1966) said that mature cysts in the goat were 580-966 by 500-830 μ , while developing ones were 200-780 by 180-670 μ . The cyst wall was composed of 2 layers and up to 40 μ thick. They found 3 sizes of merozoites. The largest were 9-12 by 1.2-1.5 μ , straight or slightly curved, with one end tapered and the other somewhat blunt, and an oval or ellipsoidal nucleus about $\frac{1}{3}$ of the body length from the blunt end. The intermediate-sized merozoites were 6-8.5 by 1.0-1.3 μ , slender, slightly curved, with tapering ends and subcentral nearly oval or spherical nucleus. The smallest merozoites were 5-8 by 1.5-1.7 μ , with a comparatively robust and stumpy form, "abruptly ending extremities," and a somewhat central nucleus. These dimensions are for smears from the schizonts fixed in alcohol and stained with hematoxylin and eosin. Sarwar (1951) found merozoites measuring 10.0 by 1.5 μ , and Soliman (1960) said that they were 6-9 by 1.2-1.8 μ . Pande et al. (1967) also found giant schizonts in the abomasum of two kids.

Triffitt (1928) described uninucleate schizonts 6-8 μ in diameter in epithelial cells of the abomasum of the goat, and 12-nucleate plasmodia (without distinct merozoites) about 16 μ long and 9.5 μ wide in a roughly spherical host cell about 28 μ in diameter. She also found mature schizonts containing merozoites similar to those she had seen in the sheep.

According to Soliman (1960), the schizonts from sheep and goats (he did not differentiate between the parasites in the 2 hosts) rested on the muscularis mucosae with their upper borders 215 μ below the intestinal lumen, while some mature cysts with diameters of 380-559 μ were only a few microns from the intestinal lumen. The cyst wall had 2 clear zones, an inner one 3-4 μ thick and an outer one 3-7 μ thick, with perpendicular striations. The merozoites ("spores") were sickle-shaped, with a nucleus at the blunt end and the other end sharp and hyaline with a distinct granule between it and the cell nucleus; the unfixed merozoites were 6-9 μ long and 1.2-1.8 μ wide.

Various authors have described giant schizonts (globidia) from the small intestine of sheep and goats (and even from the cecum of the sheep—Bhatia and Pande, 1966b). Whether they belong to the same species as the abomasal schizonts is unknown.

Prepatent Period. Unknown.

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. *Capra hircus* (domestic goat); *Capra sibirica* (Siberian wild goat). In addition, Abdussalam (1953) found this species in a wild sheep *Pseudois nahoor* (*Ovis nahura*) which died in the Zoological Gardens at Lahore, Pakistan.

Actually, it is uncertain whether this species occurs in both sheep and goats even though it has been reported from them. Further study may reveal that these hosts have different species which are at present assigned to "*E. gilruthi*."

Location. Abomasum.

Geographic Distribution. Worldwide.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. This form is very common in some parts of the world, but not in others. Gilruth (1910) found it in Australia. Chatton (1910a,b) found it in the abomasa of almost all the sheep he examined in France. Triffitt (1925) found it in 92% of 138 sheep slaughtered in London. Alicata (1930) found it in 9% of 78 sheep in Indiana, 11% of 101 from West Virginia and 8% of 72 from Idaho. Marsh and Tunnicliff (1941) found it in Montana, and Morgan and Hawkins (1952) said that it had also been seen in Wyoming and Michigan. We have seen it in a very small percentage of sheep at the Illinois State Veterinary Diagnostic Laboratory. Sarwar (1951) found it in 34% of the sheep and goats slaughtered at Lahore, Pakistan, and found it in as many as 94% in other parts of East Pakistan. Soliman (1958) found it in 18% of 250 sheep slaughtered in Egypt and in 32% of 425 sheep in the Sudan. Gilruth (1910) and Rac and Willson (1959) found it in sheep in Australia. Canham (1931) found it in sheep in Natal. Bhatia and Pande (1966a) and Matta and Pande (1966) found it commonly in sheep in India.

Triffitt (1928) found it in the goat in England. Ferguson and Goldsby (1961) found it in all of 15 goats in Missouri and Arkansas. Sarwar (1951) found it in 34% of the goats slaughtered at Lahore, Pakistan; Soliman (1958) in 28% of 150 goats slaughtered in Egypt; Soliman (1960) in 40% of 240 goats in the Sudan; and Pande and Bhatia (1966) in 9% of 100 goats in Mathura, Uttar Pradesh, India. Mugera and Bitakaramire (1968) found it in the goat in Kenya. Hilgenfeld (1966) reported giant schizonts which he assigned to this species in the submucosa of the large and small intestines of the Siberian wild goat *Capra sibirica*.

Remarks. "*E. gilruthi*" is undoubtedly the schizont of one or more species of coccidia of the sheep and goat already known from the

oocysts. However, we do not know what species it or they may be. Reichenow (1929) said that it was very probably *E. intricata*. Becker (1956) agreed and, since the name *E. gilruthi* has priority, synonymized *E. intricata* with it. However, Davis and Bowman (1965) found that *E. intricata* does not have giant schizonts, so this species cannot be *E. gilruthi*.

Eimeria granulosa Christensen, 1938

(PLATE 57, FIGS. 246-247)

Description. The following description is based on those of Christensen (1938b), Shah (1963) and Jackson (1964) for *E. granulosa* from the domestic sheep. Oocysts piriform, ellipsoidal or shaped like a stout, broad-shouldered urn, with a micropyle and micropylar cap at the broad end. Oocysts 22-35 by 17-25 μ with a mean of 29.4 by 20.9 μ (Christensen, 1938b), 30-35 by 21-22 μ with a mean of 31 by 22 μ (Shah, 1963) or 28-37 by 21-26 μ with a mean of 32.5 by 24.0 μ (Jackson, 1964). Oocyst wall composed of 2 layers, the outer one smooth, pale yellow to yellowish green, 0.4-0.6 μ thick, and the inner one brownish yellow and 0.8 μ thick. Oocyst wall lined by a membrane often slightly wrinkled at micropylar end. Micropylar cap prominent, faintly brownish, shaped like a truncate cone with a slightly convex top, easily dislodged, 1-3 μ high and 5-12 μ wide. Two or more oocyst polar granules ordinarily present (Shah, 1963) or absent (Christensen, 1938b). Oocyst residuum absent. Sporocysts ovoid or elongate ovoid, rounded at both ends. Stieda body faintly perceptible (Shah, 1963). Sporocysts 13-16 by 8-9 μ with a mean of 15 by 8 μ (Shah, 1963; Jackson, 1964). Sporocyst residuum present, usually consisting of granules scattered loosely in sporocyst but forming a compact mass in a few sporocysts. Sporozoites elongate, with one end narrower than the other, lying lengthwise, head to tail, in sporocysts, with 1-3 clear globules.

According to Honess (1942), *E. granulosa* in the bighorn sheep was identical in all respects except size with Christensen's (1938b) description. The oocysts he found in this host were 33-39 by 24-25 μ with a mean of 36.2 by 24.7 μ ; their micropylar caps were 2-4 μ high and 8-12 μ wide, with a mean of 3.1 by 9.8 μ .

According to Shah and Joshi (1963), the oocysts in the domestic goat were ellipsoidal or piriform, slightly flattened at the micropylar end, 30-34 by 20-26 μ with a mean of 32 by 23 μ . Oocyst wall composed of 2 layers, the outer one smooth, pale yellow to yellowish brown

and 1 μ thick, the inner one brownish yellow, 0.6 μ thick. Micropylar cap prominent, faintly brownish, cone-shaped, easily dislodged, 2-3 μ high and 8-10 μ wide with a mean of 3 by 9 μ . Three or more oocyst polar granules present. Oocyst residuum absent. Sporocysts elongate ovoid, with faintly perceptible Stieda body, 13-15 by 8-9 μ . Sporocyst residuum present. Sporozoites elongate, lying lengthwise head to tail in sporocysts, with 1-2 clear globules in each sporozoite.

Sporulation Time. Three to 4 days according to Christensen (1938b).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. *Ovis canadensis* (Rocky mountain bighorn sheep), *Capra hircus* (domestic goat).

Location. Unknown. Oocysts found in feces.

Geographic Distribution. Worldwide.

Pathogenicity. Unknown.

Cross-Transmission Studies. Krylov (1961) failed to transmit *E. granulosa* from the sheep to a 3-month-old kid or a 2-month-old lamb.

Prevalence. Christensen (1938b) found this species in 10% of 100 sheep from Maryland and New York; Hammond and Hamilton (1940, 1941) found it in 16% of 50 sheep in northern Utah; Shah (1963) in 4% of 153 sheep from Illinois and other states; Joyner et al. (1966) in 9% of 198 sheep in England; Jacob (1943) in 1% of 100 sheep in Germany; Patyk (1965) in 3% of 222 lambs aged 1-8 months in Poland; Merdivenci (1959) in 6% of the sheep he examined in Turkey; and Wiesenhütter (1965) in 13% of 642 sheep and none of 413 goats in Syria. Honess (1942) remarked that *E. granulosa* was more frequent and numerous in bighorn sheep than in domestic sheep in Wyoming. Merdivenci (1959) found it in 6% of the goats he examined in Turkey, and Sayin (1966) in 3% of 900 Angora goats in Turkey. Shah and Joshi (1963) found it in 1% of 300 goats in Madhya Pradesh, India, and Jha and Subramanian (1966) in 10% of 243 goats in Uttar Pradesh, India.

Eimeria pallida Christensen, 1938

(PLATE 57, FIG. 248-249)

Description. The forms in the sheep and goat are described separately. That in the sheep is based on Christensen (1938b), Shah (1963)

and Jackson (1964). That in the goat is based on Shah and Joshi (1963).

Oocysts in the sheep ellipsoidal, 12-20 by 8-15 μ with a mean of 14 by 10 μ (Christensen) 15 by 11 μ (Shah) or 14 by 11 μ (Jackson). Oocyst wall smooth, colorless to very pale yellow or yellowish green, composed of 2 layers 0.5 μ in total thickness; outer layer accounts for almost the whole thickness of the wall; inner layer appears simply as a dark line on inner surface of wall. Micropyle imperceptible, perhaps absent. Micropylar cap absent. Oocyst polar granule present (absent according to Christensen). Oocyst residuum absent. Sporocysts elongate ovoid, 6-9 by 4-6 μ with a mean of 7 by 4 μ (Shah) or 8 by 4 μ (Jackson). Stieda body absent. Sporocyst residuum present. Sporozoites elongate, usually lying lengthwise head to tail in sporocysts, but often with a tendency to lie crosswise in them. Sporozoites with a single clear globule.

Oocysts in the goat ellipsoidal or slightly ovoid, 13-18 by 10-14 μ with a mean of 16 by 12 μ . Oocyst wall smooth, colorless to very pale yellow, composed of 2 layers of which the outer is 0.6 μ thick and the inner one is merely a dark line on the inner surface of the wall. Micropyle imperceptible. Micropylar cap absent. Oocyst polar granule present. Oocyst residuum absent. Sporocysts elongate ovoid, 6-9 by 4-5 μ with a mean of 7 by 5 μ . Stieda body absent. Sporocyst residuum present. Sporozoites elongate, lying lengthwise head to tail in sporocysts, with a single clear globule.

Sporulation Time. One day according to Christensen (1938b); 2-3 days at 21-23 C according to Ray (1961).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. *Capra hircus* (domestic goat), *C. ibex* (Alpine ibex) (See Couturier, 1962).

Location. Unknown. Oocysts found in feces.

Geographic Distribution. Presumably worldwide.

Pathogenicity. Unknown.

Cross-Transmission Studies. Fitzsimmons (1964) failed to infect 2 coccidia-free kids 50 and 58 days old with "*Eimeria pallida*/*Eimeria parva*" and other coccidia from a sheep, although he did succeed in infecting a control, coccidia-free lamb; however, *Eimeria pallida*/*parva* constituted only 1% of the coccidia passed by the lamb.

Prevalence. Christensen (1938b) found this species in 10% of 100 sheep from Maryland and Wyoming; Hammond and Hamilton (1940, 1941) found it in 4% of 50 sheep in northern Utah; Shah (1963) in

6% of 153 sheep from Illinois and other states; Joyner et al. (1966) in 37% of 198 sheep in England; Patyk (1965) in 3% of 222 lambs aged 1-8 months in Poland; Merdivenci (1959) in 4% of the sheep and 3% of the goats he examined in Turkey; Sayin (1966) in 2% of 900 Angora goats in Turkey; Wiesenhütter (1965) in 1% of 642 sheep and none of 413 goats in Syria; Shah and Joshi (1963) in 0.3% of 300 goats in Madhya Pradesh, India; Jha and Subramanian (1966) in 6% of 243 goats in Uttar Pradesh, India; and Fernando (1957) in 6% of 62 goats in Ceylon.

Remarks. Kotlán, Pellérdy and Versényi (1951a) and Pellérdy (1965) considered *E. pallida* a synonym of *E. parva*, but Shah (1963) and Jackson (1964) verified that the two are different.

Eimeria hawkinsi Ray, 1952

(PLATE 57, FIG. 250)

Description. According to Ray (1952, 1961), the oocysts are spherical to subspherical. Although he said that the wall "had a single contour," he described 2 walls; the "endocystic" wall was darker and more prominent than the "ectocystic" wall; the general color of the oocyst was light grayish pink in daylight. Oocysts 20-25 by 15-22.5 μ with a mean of 22.4 by 18.4 μ . Micropyle present. There is apparently no true polar cap although Ray said that there was one. He said (1952), "The polar cap seemed to be a protruberance [*sic*] of the endocystic wall and its protruded portion had just come out of the endocystic wall in the form of a triangle, the base of which was embedded in the endocystic wall. The micropyle was a very minute gap between the base of the triangle and the endocystic wall." In his later (1961) paper, Ray illustrated a triangular protrusion through the micropyle; his drawing looked like either a membrane containing the oocyst contents protruding through a single-layered wall and coming to a point, or a double-layered wall with the inner border of the inner layer protruding through the oocyst wall and coming to a point outside it. Whatever it was, it was not a true polar cap. Oocyst polar granules apparently absent. Oocyst residuum absent. Sporocysts piriform, 10-15 by 7.5-10 μ with a mean of 11 by 8 μ . Sporocyst residuum present.

Sporulation Time. Five to 6 days at 21-23 C according to Ray (1961); 10 hours at 37 C according to Ray (1952).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. *Capra hircus* (domestic goat).

Location. Oocysts found in feces.

Geographic Distribution. India. Ray (1961) reported this species from sheep in Madhya Pradesh, Uttar Pradesh, Madras, and Orissa. He reported it from goats in Uttar Pradesh, Bengal, and Kashmir.

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Jha and Subramanian (1966) reported this species from 18% of 243 goats in Uttar Pradesh, India.

Remarks. While Ray (1952, 1961) considered that this form was different from any previously reported from sheep or goats because of its peculiar "polar cap," Pellérdy (1965) said that it was a synonym of *E. arloingi* (i.e., *E. ovina*). Shah and Joshi (1963) said that, except for the shape of the micropylar cap and slightly larger sporocyst size, *E. hawkinsi* closely resembles *E. crandallis*, and they thought that it might not be a valid species. Acceptance as a separate species will depend upon further study by other investigators. Jha and Subramanian (1966) said that they would report on the validity and structure of this species in a later communication, but we have not seen it if it has appeared.

Eimeria punctata Landers, 1955

(PLATE 58, FIGS. 251-253)

Eimeria honessi Landers, 1952.

[non] *E. honessi* Alderson, 1951 *nomen nudum*.

[non] *E. media* var. *honessi* Carvalho, 1943.

Description. The following description of *E. punctata* from sheep is based on Landers (1952) and Shah (1963). Oocysts ellipsoidal or subspherical to ovoid, slightly flattened at micropylar end, 18-28 by 16-21 μ with a mean of 21 by 18 μ (Landers) or 26 by 19 μ (Shah). Oocyst wall with conspicuous, uniform, cone-shaped pits about 0.4-0.5 μ in diameter, composed of 2 layers, the outer layer 1.4 μ thick, colorless to yellowish, and the inner layer 0.4 μ thick, greenish to brownish yellow. Micropyle at small end of oocyst. Micropylar cap imperceptible to prominent, colorless, cone-shaped, generally 5-7 μ wide and 1-2 μ high with a mean of 6 by 2 μ . Oocyst polar granule ordinarily present (absent according to Landers). Oocyst residuum usually present (absent according to Landers). Sporocysts elongate ovoid (Landers said that they were spherical or ellipsoidal, but illustrated them as piriform). Stieda body faintly perceptible. Sporocysts 12-15 by 7-9 μ

with a mean of 13 by 8 μ (Shah) or 8 μ in diameter or 10 by 7 μ (Landers). Sporocyst residuum present. Sporozoites elongate, lying head to tail in sporocysts, with a single clear globule at one end.

Chevalier (1966) described the oocysts in the goat. They were ovoid to ellipsoidal, 21-31 by 15-23 μ with a mean of 26 by 19.5 μ , with a broad micropyle and a high, transparent micropylar cap, a greenish yellow to brownish green wall, composed of several layers and pitted like a thimble; the sporocysts were slender but could not be measured because of the thickness of the oocyst wall. For the same reason he could not determine whether polar granule, oocyst residuum, or sporocyst residuum were present.

Sporulation Time. According to Landers (1952) the sporulation time of *E. punctata* from the sheep is 36-48 hours at room temperature. According to Chevalier (1966), the sporulation time of *E. punctata* in the goat is 2-5 days.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. *Capra hircus* (domestic goat) (Chevalier, 1966).

Location. Unknown. Oocysts found in feces.

Geographic Distribution. North America (Wyoming, Illinois), Europe (Germany).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Landers (1952) found this species in 2 of 9 sheep in Wyoming, Shah (1963) in 1% of 153 sheep in Illinois, Chevalier (1966) in 1% of 40 goats in Germany, and Sayin (1966) in 0.1% of 900 Angora goats in Turkey.

Remarks. The descriptions of Landers (1952) and Shah (1963) of *E. punctata* from sheep and of Chevalier (1966) of *E. punctata* from the goat differ in some respects. Further study is needed to determine whether they were all referring to the same species.

Alderson (1951) named *E. honessi* from the elk *Cervus canadensis nelsoni* in Wyoming, but did not describe it. His name is therefore a *nomen nudum* besides being a homonym of *E. media* var. *honessi* Carvalho, 1943.

Eimeria ovina n. sp.

(PLATE 58, FIGS. 254-256)

Eimeria arloingi forma *ovina* Krylov, 1961.

Eimeria arloingi Auctores from sheep.

Eimeria faurei (Moussu and Marotel, 1902) of Yakimoff, 1931a, of Tsygankov, Paichuk and Balbaeva, 1963, and of some other Russian authors.

[non] *Eimeria arloingi* (Marotel, 1905) Martin, 1909.

[non] *Eimeria faurei* (Moussu and Marotel, 1902) Martin, 1909.

Description. The following description is based on those of Honess (1942), Kamalapur (1961), Jackson (1964), and Chevalier (1965), who described this species from sheep and separated it from *E. crandallis* and *E. ahsata*. Other descriptions cannot be used because they were deficient in one of these 2 points. Oocysts ellipsoidal to ovoid, generally with rather straight sides, slightly flattened at the micropylar end, 23-36 by 16-24 μ with a mean of 27 by 20 μ (Honess, 1942), 29 by 21 μ (Kamalapur, 1961) 30 by 20 μ (Jackson, 1964) (Jackson's measurements did not include the height of the cap). Oocyst wall composed of 2 layers; outer one smooth (occasionally roughened by regular circular pits in the surface according to Jackson, 1964), greenish (Kamalapur, 1961) or yellow-brown to orange (Jackson, 1964), about 1.3 μ thick; inner layer a brownish-yellow membrane 0.5 μ thick (Kamalapur, 1961) or a dark brown to black line (Jackson, 1964). Micropyle present. Micropylar cap present, dome- to mound-shaped, colorless, 1-3 μ high and 4.5-10 μ wide with a mean of 2 by 7 μ (Kamalapur, 1961) or 2 by 8 μ (Jackson, 1964). One or more oocyst polar granules present, sometimes as small shattered particles. Oocyst residuum absent. Sporocysts elongate ovoid, with one end narrow but blunt. Stieda body absent (Kamalapur, 1961) or inconspicuous (Jackson, 1964). Sporocysts 11-17 by 6-9 μ with a mean of 14 by 7.5 μ (Kamalapur, 1961) or 15 by 7 μ (Jackson, 1964). Sporocyst residuum present as small granules arranged in rows, groups, or rosettes. Sporozoites elongate, lying head to tail in sporocysts. Sporozoites with a large clear globule at one end and a smaller one at the other end.

Honess (1942) said that the oocysts of *E. ovina* (syn., *E. arloingi*) from *Ovis canadensis* were 24-30 μ long and had mean dimensions of 27.5 by 22.0 μ .

Sporulation Time. Two to 4 days according to Chevalier (1965).

Schizogony and Gametogony. Lotze (1953) studied the life cycle of *E. ovina* (syn., *E. arloingi*) in experimentally infected lambs. The sporozoites emerge from the oocysts in the small intestine, enter the crypts of Lieberkühn, and penetrate through the tunica propria into the interior of the villi. Here they enter the endothelial cells lining the central lacteals and grow. The host cell also grows, and its nucleus becomes very large. There is apparently only one generation of

schizonts and merozoites. The schizonts become mature 13-21 days after infection. At this time they are about 122-146 μ in diameter and contain a large number (perhaps hundreds of thousands) of merozoites about 9 μ long and 2 μ wide.

The merozoites break out of the schizonts and enter the epithelial cells of the small intestine. Sometimes only a small group of cells at the bottom of the crypts is parasitized, but in heavy infections practically all the epithelial cells of the villi are invaded. The infected villi are enlarged and grayish. Some of these merozoites become microgamonts; these form many microgametes, leaving a large mass of residual material. Most of the merozoites become macrogametes, which contain large plastic granules when mature.

Following fertilization, the macrogametes turn into oocysts, which break out of the host cells and are first seen in the feces 20 days after infection. Their numbers increase for about 5 days and then decrease at about the same rate for the next 5 days. Thus the patent period is about 10 days following a single exposure.

N. Singh and Pande (1967) found endogenous stages in the small intestine of sheep in India that they thought were those of *E. ovina*. However, they were dealing with mixed infections.

Prepatent Period. Nineteen days according to Lotze (1953).

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. *Ovis canadensis* (Rocky Mountain bighorn sheep), *O. ammon* (argali), *O. musimon* (mouflon).

Location. Small intestine.

Geographic Distribution. Worldwide.

Pathogenicity. Lotze (1952) studied the pathogenicity of *E. ovina* (syn., *E. arloingi*) in 3-month-old lambs experimentally inoculated with 200,000 to 60 million oocysts. No visible signs were produced by infections with 1 million oocysts or less. In lambs inoculated with 3 or 5 million oocysts, the feces became soft on the 13th day and then returned to normal during the next 6 days. The health, general condition and weight gains of these animals were not affected.

Severe diarrhea was produced with higher doses, but none of the animals died although one was killed in extremis. In general, the experimentally infected lambs appeared normal up to the 13th day after inoculation, when their feces became soft. In the more heavily infected lambs the feces then became watery, and diarrhea was severe beginning on the 15th day. Blood-tinged mucus was passed by affected lambs only occasionally. The feces began to return to normal on the 17th day and were usually nearly normal by the 20th day. Lambs with marked diarrhea became weak and refused feed.

At autopsy, only a few small, slightly hemorrhagic areas scattered throughout the lining of the small intestine were seen up to the 13th day. From the 13th to 19th days the small intestine was more or less thickened and edematous, and thick, white opaque patches made up of groups of heavily parasitized villi were present.

The villi containing the schizonts become thin-walled sacs and are presumably destroyed. The sexual stages are clustered in the epithelial cells of the villi and destroy these cells when they emerge. However, they do not do as much damage as the asexual stages, since the condition of affected animals appeared to improve before oocysts were shed.

E. ovina is less pathogenic than *E. ninakohlyakimovae* or *E. ahsata*.

Cross-Transmission Studies. Krylov (1961) attempted to transmit *E. ovina* from sheep to goats and *E. arloingi* from goats to sheep. He failed to produce clearcut infections in 9 goats 3 months to 2 years of age by feeding as many as 100,000 oocysts of *E. ovina* from sheep or in 3 lambs 1.5 months old by feeding 210,000 oocysts of *E. arloingi* from goats. He had no difficulty, however, in infecting 4 lambs 1.5-2.0 months old with *E. ovina* from sheep.

Krylov's failure to infect goats with the form from sheep and vice versa led him to conclude that the forms in the 2 hosts are biological races or xenodemes; he therefore gave the name *E. arloingi* forma *ovina* to the form in the sheep. However, his work is subject to some criticism because it is not known whether his experimental animals had had previous natural infections or were free of coccidia at the time of exposure.

Lotze et al. (1961) were unable to produce patent infections in goats with *E. ovina* (syn., *E. arloingi*) from sheep or in sheep with *E. arloingi* from goats. However, they (1961, 1964) found schizonts in the mesenteric lymph nodes of both sheep and goats fed *E. ovina* (syn., *E. arloingi*) oocysts from sheep. The schizonts in the sheep were more numerous than in the goats; they appeared normal, were about 30-360 μ in diameter, and contained merozoites that appeared to be approaching maturity. The schizonts in the goats were about 32-100 μ in diameter, appeared somewhat abnormal, and their merozoites were not as mature as those in the sheep; presumably they later degenerated. Bhatia and Pande (1967a) found giant schizonts in the mesenteric lymph nodes of a naturally infected kid in India, but were unable to assign them to a species.

Tsygankov, Paichuk and Balbaeva (1963) were unable to transmit *E. ovina* (which they called *E. faurei*) from the sheep to one saiga and 4 kids, although they produced a patent infection in a lamb. They were unable to transmit *E. arloingi* (which they called *E. faurei*)

from the goat to one saiga and one lamb although they produced a patent infection with it in a kid.

Prevalence. This is probably the commonest coccidium of sheep. Christensen (1938b) found it in 90% of 100 sheep from Idaho, Maryland, New York, and Wyoming; Hammond and Hamilton (1940, 1941) in 94% of 50 sheep in northern Utah; Shah (1963) in 53% of 153 sheep from Illinois and other states; Balozet (1932a) in 52% of 63 sheep in Tunisia; Jacob (1943) in 58% of 100 sheep and Chevalier (1965) in 17% of 183 sheep in Germany; Joyner et al. (1966) in 95% of 198 sheep in England; Svanbaev (1957) in 52% of 302 sheep in Kazakhstan; Patyk (1965) in 45% of 222 lambs aged 1-8 months in Poland; Merdivenci (1959) in 50% of the sheep with coccidiosis that he examined in Turkey; Wiesenhütter (1965) in 94% of 642 sheep in Syria; and Deom and Mortelmans (1956) in 69% of 230 sheep in Belgian Congo.

Remarks. There is a structural difference between the oocysts of *E. arloingi* from the goat and the so-called *E. arloingi* from sheep. The oocysts of the former are ellipsoidal, while those of the latter generally have rather straight sides. This difference was noted by Lotze (personal communication) and can also be seen by comparing the illustrations of "*E. arloingi*" from the sheep given by Kamalapur (1961) with that of *E. arloingi* from the goat given by Levine, Ivens and Fritz (1962).

On the basis of the above evidence, it appears that the "*E. arloingi*" of sheep and the *E. arloingi* of the goat are not the same. We therefore believe it best to use the name *E. ovina* n. sp. for the form from the sheep, since *E. arloingi* was first described from the goat.

***Eimeria gonzalesi* Bazalar and Guerrero, 1970**

(PLATE 57, FIG. 245; PLATE 65, FIG. 291)

Eimeria sp. Patyk, 1965.

Description. Oocysts ellipsoidal or ovoid, 26-38 by 18-26 μ , slightly flattened at the micropylar end. Oocyst wall smooth, 1-2 μ thick (mean 1.8 μ), composed of 2 layers, the outer being transparent and the inner yellowish brown. Micropylar cap 6-9 μ wide and 1-3 μ high with a mean of 8 by 2 μ . Oocyst residuum absent. Oocyst polar granule present. Sporocysts ovoid, 12-15 by 6-9 μ with a mean of 14 by 8 μ , with a slightly perceptible Stieda body and a residuum. Sporozoites with 2-3 clear globules each.

Sporulation Time. Four to 6 days according to Patyk (1965).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. None.

Location. Unknown. Oocysts found in feces.

Geographic Distribution. South America (Peru), Europe (Poland).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Bazalar and Guerrero (1970) found this species in 17% of 240 sheep in Peru. Patyk (1965) found it in 3% of 222 lambs aged 1-8 months in Poland.

Remarks. This species resembles *E. ovina* but differs in that its micropylar cap extends a little way down the sides of the oocysts and its oocyst wall does not have straight sides. In addition, since Patyk (1965) and Bazalar and Guerrero (1970) both reported *E. ovina* (as *E. arloingi*) from their sheep and considered this form different, it may well be a new species.

***Eimeria* sp. Mincheva, Sherkov, Monov, Kyurtov, Bratanov, Meshkov and Donev, 1966**

Description. Oocysts spherical to ellipsoidal, with a thick, smooth colorless wall. Micropyle prominent. Spherical oocysts 10 μ in diameter, ellipsoidal oocysts 10 by 6 μ . Sporocysts spherical. No other information given.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Ovis aries* (domestic sheep).

Other Hosts. None.

Location. Oocysts in feces.

Geographic Distribution. Europe (Bulgaria).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

***Eimeria ahsata* Honess, 1942**

(PLATE 58, FIG. 257; PLATE 59, FIGS. 258-259)

Eimeria ah-sa-ta Honess, 1942.

Description. Oocysts ellipsoidal to somewhat ovoid, slightly flattened at the micropylar end, which is almost always the smaller one.

According to Levine et al. (1962), the oocysts from the domestic sheep in Illinois are 36-44 by 22-29 μ with a mean of 40 by 26 μ . Those originally described from the domestic sheep by Honess (1942) in Wyoming were 29-37 by 17-28 μ with a mean of 33 by 23 μ ; those described by him from the bighorn sheep were 30-40 by 20-30 μ with a mean of 33 by 24 μ . The oocysts described from the domestic sheep in Illinois by Kamalapur (1961) were 23-48 by 20-28 μ with a mean of 36 by 24 μ ; those described from this host in Rumania by Donciu (1961) were 31-39 by 22-28 μ ; those described from this host in Australia by Jackson (1964) were 34-47 by 22-29 μ with a mean of 39.4 by 25.6 μ (not counting the micropylar cap which averaged 9.9 μ wide and 2.6 μ high); those described from this host in Germany by Chevalier (1965) were 30-39 by 18-30 μ ; those reported from this host in Senegal by Vassiliades (1965) were 30-34 by 18-24 μ with a mean of 31.2 by 20.1 μ . Oocyst wall smooth, lavender to pinkish yellow to light brown, composed of 2 layers 0.9-1.3 μ in total thickness. The true outer layer accounts for almost the whole thickness of the wall; in intact oocysts the inner layer appears simply as a dark line on the inner surface of the wall and may sometimes be somewhat wrinkled at the micropylar end; in crushed oocysts the inner layer is a distinct membrane separate from the outer layer. Micropyle present. Micropylar cap present, dome-shaped, 0.4-4.0 μ high and 7-11 μ wide with a mean of 2 by 9 μ according to Levine et al. (1962) (mean 2.6 by 9.9 μ according to Jackson, 1964). One or occasionally more oocyst polar granules ordinarily present. Oocyst residuum absent (Jackson, 1964, saw an oocyst residuum in a very small number of oocysts). Sporocysts elongate ovoid, rounded at both ends, with one end somewhat broader than the other. Stieda body absent (inconspicuous according to Jackson, 1964). Sporocysts 18-20 by 7-10 μ with a mean of 18 by 9 μ in the domestic sheep according to Levine et al. (1962); 12-22 by 7-10 μ with a mean of 17 by 6 μ in this host according to Kamalapur (1961); 10-12 by 6-8 μ according to Donciu (1961); with a mean of 19 by 8 μ according to Jackson (1964). Sporocysts in 3 hosts 9-11 by 5-8 μ according to Ryšavý (1954); in bighorn sheep with a mean of 15.4 by 7.8 μ according to Honess (1942). Sporocyst residuum present. Sporozoites elongate, lying head to tail in sporocysts. One to three clear globules present in each sporozoite.

Sporulation Time. According to Chevalier (1965) 36-72 hours.

Schizogony and Gametogony. According to Davis, Bowman and Smith (1963), the schizonts occur mostly in the central portion of the mucosa of the small intestine, most being in the jejunum; a few occur in the lacteals of the villi and a very few in the muscularis

mucosae. Ten days after experimental inoculation, the schizonts were 50 μ or less in size; at 15 days the average size was 184 by 165 μ and the largest one was 265 by 162 μ . The host wall around the schizonts was up to 9 μ thick, the larger the schizont the thinner the wall. The outer wall of the host membrane around young schizonts was fimbriated, with radially arranged fibril-like strands as long as 13 μ .

Davis, Bowman and Smith (1963) first saw gametogony 12 days after infection. The macrogametes measured 35-45 μ and the microgamonts about 26 by 36.5 μ . The gamonts and oocysts were mostly in the columnar epithelial cells lining the intestinal glands rather than in epithelial cells covering the villi as in *E. arloingi*.

Smith and Davis (1965) found that the patent period was 12 days in lambs inoculated with oocysts in dry feed and 10-11 days in lambs inoculated with oocysts in liquid.

Prepatent Period. Eighteen to 20 days according to Smith, Davis and Bowman (1960). Smith and Davis (1965) found that the prepatent period was 19 days in lambs given oocysts in dry feed, and 20-21 days in lambs given oocysts in liquid.

Type Host. *Ovis canadensis* (Rocky Mountain bighorn sheep).

Other Hosts. *Ovis aries* (domestic sheep); *O. musimon* (mouflon). In addition, Ryšavý (1954) listed the Central Asian wild goat *Capra sibirica* as a host in Czechoslovakia, and Krylov (1961) reported finding it in the domestic goat in Tadzhikistan; Jha and Subramanian (1966) in the goat in Uttar Pradesh, India; and Wiesenlütter (1965) in Syria. These reports from *Capra* may possibly have been of *E. christensen*i. Chevalier (1966) reported *E. ahsata* from the domestic goat in Germany, but his description resembles that of *E. arloingi*.

Location. Small intestine.

Geographic Distribution. United States (Alabama, Illinois, Wyoming), USSR (Tadzhikistan), Europe (Czechoslovakia, Germany, Rumania), Turkey, India (Uttar Pradesh), Australia, Africa (Senegal).

Pathogenicity. Smith, Davis and Bowman (1960) considered this species the most pathogenic of all sheep coccidia. They produced fatal infections in 4 out of 9 lambs 1-3 months old by feeding them 100,000 oocysts. The intestines of the infected lambs had thickened, somewhat edematous areas in the upper part. The Peyer's patches and the last 20-25 cm of the small intestine above the ileocecal valve were inflamed.

Smith and Davis (1965) found that as few as 31,000 oocysts caused death in lambs when administered in dry feed, and 100,000 oocysts when given in liquid.

Mahrt and Sherriek (1965) described an outbreak of coccidiosis in Illinois feeder lambs in which *E. ahsata* was the principal cause of death. Four flocks containing 2,000 lambs imported from Texas were crowded into feedlots; 33-40% had diarrhea, inappetence and depression. Weight loss was a prominent sign, and lambs which recovered did not gain weight well. About 4-6% of the lambs died. Of the oocysts present in the lambs' feces, 65% were *E. ahsata*, 18% *E. ninakohlyakimovae*, 10% *E. arloingi*, 5% *E. granulosa* and 2% *E. crandallis*. Endogenous stages of the coccidia were abundant in the small intestine.

Cross-Transmission Studies. Krylov (1961) was unable to infect a 2-year-old domestic goat with *E. ahsata* from the domestic sheep; three 3-month-old goats passed a few oocysts from 2 to 24-28 days after infection; these were probably not due to cross-transmission. Krylov (1961) was unable to infect three 1.5-month-old lambs with "*E. ahsata*" (possibly *E. christenseni*) from the domestic goat.

Prevalence. Relatively little is known about the prevalence of *E. ahsata* because it had been confused with *E. arloingi* until Smith, Davis and Bowman (1960) showed clearly that it was different. Shah (1963) found it in 24% of 153 sheep from Illinois and other states, Chevalier (1965) in 39% of 200 sheep in Germany, and Joyner et al. (1966) in 62% of 198 sheep in England. Jha and Subramanian (1966) said that they found it in 5% of 253 goats in Uttar Pradesh, India. Wiesenhütter (1965) reported it from 34% of 642 sheep and 42% of 413 goats in Syria, and Sayin (1966) said he found it in 63% of 900 Angora goats in Turkey.

Eimeria crandallis Honess, 1942

(PLATE 59, FIGS. 260-261; PLATE 60, FIGS. 264-265)

[non] *E. crandallis* Honess, 1942 of Chevalier (1966) from the goat.
? *Eimeria hirci* Chevalier, 1966.

Description. Because this species has been described from 3 different hosts, the descriptions are given separately for each.

E. crandallis was first found by Honess (1942) in the Rocky Mountain bighorn sheep *Ovis canadensis*. He illustrated the oocysts as ellipsoidal, with a micropylar cap at one end. He said that the oocysts were 17.5-23 by 17.5-22 μ with a mean of 22 by 19 μ . The polar cap varied in height from "the slightest indication" to 1.7 μ , and in width from 3.3-6.6 μ ; it averaged 0.8 by 4.9 μ . Oocyst wall colorless, faint pink or greenish, with a distinctly demarcated outer edge. Number

of layers in oocyst wall not given. Oocyst polar granule and oocyst residuum not mentioned, but polar granule shown in photomicrograph. Sporocysts 8-11 by 5-8 μ with a mean of 10 by 6 μ . Stieda body and sporocyst residuum not mentioned; not discernible in photomicrograph.

E. crandallis was described from the domestic sheep by Kamalapur (1961). Jackson (1964) also described it from sheep, but, since he may have been dealing with a mixture, we are not using his description. According to Kamalapur (1961) the oocysts are subspherical to broadly ellipsoidal, with a slightly narrower micropylar end, 18-28 by 15-20 μ with a mean of 22 by 18 μ . Oocyst wall smooth, composed of 2 layers, the outer one colorless and 0.9-1.3 μ thick with a mean of 1.1 μ , and the inner one a darkish yellow membrane lining the inner surface, slightly wrinkled at the micropylar end. Micropyle present, distinct to indistinct. Micropylar cap present or absent (present in 87% of the oocysts he studied), colorless, flat to saucer-shaped, 0.2-1.3 μ high and 2.2-5.8 μ wide with a mean of 0.8 by 4 μ . One or more oocyst polar granules usually present, often appearing as shattered small particles. Oocyst residuum absent. Sporocysts broadly ovoid, with one end pointed, sometimes blunt. Stieda body absent. Sporocysts 8-13 by 6-9 μ with a mean of 11 by 7 μ . Sporocyst residuum present as a few small granules or absent. Sporozoites at ends of sporocysts, transverse, with one or 2 clear globules.

E. crandallis was described from the domestic goat by Levine, Ivens and Fritz (1962), Shah and Joshi (1963) and Singh (1964). The oocysts are ellipsoidal, slightly flattened at the micropylar (small) end, 19-27 by 14-20 μ with a mean of 22-23 by 18-19 μ (17-24 by 17-22 μ according to Singh, 1964). Oocyst wall composed of 2 layers, the outer one smooth, colorless and 0.8-0.9 μ thick, and the inner one light brownish yellow and 0.4 μ thick. Inner layer forms a membrane which is sometimes slightly wrinkled at the micropylar end. Micropyle present, usually indistinct, rarely invisible; oocyst wall relatively thin at micropylar end. Micropylar cap absent or present (present in 25% of Levine, Ivens and Fritz's material, and presumably more often in Shah and Joshi's material), colorless, rather flat to mound-shaped, sometimes slightly pointed, when present 0.4-2 μ high and 3-6 μ wide with a mean of 1 by 3-5 μ . One to several oocyst polar granules present, often appearing shattered into coarse or fine particles. Oocyst residuum absent. Sporocysts broadly ovoid, usually rather pointed at one end, sometimes blunt. Stieda body ordinarily absent, but occasionally present and minuscule. Sporocysts 8-12 by 6-8 μ with a mean of 10-11 by 7 μ (14 by 4 μ according to Singh's (1964) text, but about 10 by 4-6 μ according to his drawing). Sporocyst residuum

usually present, sometimes absent or consisting of a few sparse granules. Sporozoites lie at more or less of an angle in the sporocysts, but primarily at the ends. Sporozoites sometimes contain one or 2 clear globules.

Descriptions given by others (Ryšavý, 1954; Donciu, 1961; Ray, 1961) did not differentiate between the forms in different hosts.

Sporulation Time. One to 3 days at room temperature in India, according to Singh (1964).

Schizogony and Gametogony. Unknown. See the discussion of *E. arloingi*.

Prepatent Period. Fifteen to 20 days according to Pout (1965).

Type Host. *Ovis canadensis* (Rocky Mountain bighorn sheep).

Other Hosts. *Ovis aries* (domestic sheep), *O. musimon*, *O. ammon*. In addition, this species has been reported from the domestic goat *Capra hircus*, from *C. sibirica*, *C. aegagrus*, *Capreolus capreolus*, *Cervus elaphus*, *Dama dama*, *Rupicapra rupicapra* and *Gazella subgutturosa* (all but the bighorn sheep, domestic sheep and domestic goat by Ryšavý, 1954 and Donciu, 1961). The validity of the identification of this species in goats is discussed below. It is extremely dubious that it occurs in any other host genera.

Location. Small intestine, extending anteriorly from the ileocecal valve (Pout, 1965).

Geographic Distribution. Form in bighorn sheep: USA (Wyoming).

Form in domestic sheep: USA (Alabama, Illinois), Europe (England, Czechoslovakia, Poland, Rumania), USSR (Tadzhikistan), India (Bombay, Bihar, Kashmir, Madhya Pradesh, Madras, Uttar Pradesh), Australia, Africa (Senegal).

Form in domestic goat: USA (Illinois), Europe (Czechoslovakia, Germany, Rumania), India (Bihar, Madhya Pradesh, Orissa, Uttar Pradesh).

Pathogenicity. Smith and Davis (1961) found that inoculations of 100,000 to 3 million infective oocysts from sheep in Alabama had no noticeable harmful effects in lambs. Pout (1965) found that 2,500 oocysts from sheep in England daily for 7 days had no noticeable effect, whereas 250,000 oocysts daily for 7 days caused lassitude, soft, gray feces, indications of abdominal pain, and, in one lamb, death. The ileum was slightly thickened and the ileo-colic lymph nodes were enlarged.

Cross-Transmission Studies. Krylov (1961) was unable to infect two 3-month-old kids with *E. crandallis* from sheep, and obtained dubious results in an attempt to infect 2 one-year-old goats.

Prevalence. Shah (1963) found *E. crandallis* in 24% of 153 sheep

from Illinois and other states, Joyner et al. (1966) in 90% of 198 sheep in England, Patyk (1965) in 1% of 222 lambs aged 1-8 months in Poland, Sayin (1966) in 11% of 900 Angora goats in Turkey, and Wiesenhütter (1965) in 25% of 642 sheep and 22% of 413 goats in Syria. Shah and Joshi (1963) found it in 10% of 300 goats in Madhya Pradesh, India; Singh (1964) in 29% of 214 goats; and Jha and Subramanian (1966) in 13% of 243 goats in Uttar Pradesh, India.

Remarks. There is a question whether *E. crandallis* parasitizes both sheep and goats, even though it has been reported from both hosts. The oocysts described from the 2 hosts appear to be structurally identical, but the fact that Krylov (1961) failed to transmit this coccidium from sheep to goats suggests that there must at least be host-specific strains or demes. At any rate, we do not believe that reports of this species from host genera other than *Ovis* and *Capra* can be accepted without proof of cross-transmissibility.

Eimeria arkhari Yakimoff and Matschoulsky, 1937

(PLATE 10, FIG. 60)

Description. Oocysts ellipsoidal, often ovoid, with a double-contoured wall (illustrated as composed of a single layer) up to 1 μ thick, sometimes yellowish. Micropyle absent. Oocysts 20-24 by 18-20 μ with a mean of 22.4 by 17.4 μ . Oocyst polar granule and oocyst residuum absent. Sporocysts ellipsoidal, 6-8 by 6 μ . Sporocyst residuum absent. Sporozoites sausage-shaped.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Ovis vignei* (urial, arkhar) (Yakimoff and Matschoulsky, 1937a gave the host as "*Ovis vignei* s. *O. arkhar*").

Other Hosts. *Ovis ammon polii* and *O. a. sewerzowi* (argali) (Yakimoff and Matschoulsky, 1940).

Location. Unknown. Oocysts found in feces.

Geographic Distribution. USSR (Tashkent zoo).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. Pellérdy (1965) said that this species was difficult to distinguish from *E. faurei* and *E. ninakohlyakimovae*; its one clearly distinctive feature, he said, might be the absence of a sporocyst residuum, which differentiated it from all other sheep coccidia.

GENUS *ISOSPORA* SCHNEIDER, 1881

In this genus, the oocyst has two sporocysts, each containing four sporozoites. The synonymy of this genus has been given by Pellérdy (1963).

Isospora orlovi Tsygankov, 1950

(PLATE 59, FIG. 262)

Description. Oocysts ellipsoidal, ovoid, piriform, cylindrical or figure-8 shaped, dark gray. Oocyst wall smooth, about $1\ \mu$ thick, described as composed of 2 layers (but illustrated with one layer), the outer one yellow-green or light green, the inner layer rose, dark rose, red or brown. Oocysts 27-35 by 15-20 μ . Micropyle absent. Oocyst polar granule and oocyst residuum absent. Sporocysts ellipsoidal, ovoid or spherical, 15-20 by 13-17 μ (the spherical ones 13.5-15 μ in diameter). Stieda body absent. Sporocyst residuum spherical or shapeless. Sporozoites elongate ellipsoidal, 7-10 by 4-6 μ .

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. Camel, species not stated.

Location. Oocysts in feces.

Geographic Distribution. USSR (Kazakhstan).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

***Isospora rangiferis* Yakimoff, Matschoulsky and Spartansky, 1937**

(PLATE 61, FIG. 272)

Isospora sp. Yakimoff, Sokoloff and Matschoulsky, 1936.

Description. Oocysts ovoid or subspherical, 26-32 by 24-30 μ with a mean of 29 by 24.5 μ . Oocyst wall described as double-contoured, illustrated with a single layer. Micropyle absent. Oocyst residuum absent. Oocyst polar granule present. Sporocysts ovoid with a "double-contoured" wall and prominent Stieda body. Sporocyst residuum present. Sporocysts described in text as 16-19 by 8-12 μ , listed in table as 12-16 by 8-12 μ . Sporozoites comma-shaped, illustrated with a clear globule at the large end.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Rangifer tarandus* (reindeer).

Location. Feces.

Geographic Distribution. USSR (Murmansk area, Kola Peninsula).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Yakimoff, Sokoloff and Matschoulsky (1936) found this species in 4 out of 39 reindeer from the Murmansk area. Yakimoff, Matschoulsky and Spartansky (1937) found it in 1 out of 27 reindeer from the Kola Peninsula.

***Isospora capreoli* Svanbaev, 1958**

(PLATE 59, FIG. 263)

Description. Oocysts ovoid or piriform, 40-46 by 28-32 μ with a mean of 43 by 31 μ . Micropyle prominent, 4-5 μ wide, occasionally with an inconspicuous micropylar cap. Oocyst wall smooth, apparently composed of 2 layers, 2-4 μ thick, yellowish brown or brown, with

the inner layer radially striated. Oocyst residuum present. Oocyst polar granule absent. Sporocysts piriform or ovoid, 19-25 by 11-16 μ with a mean of 21.7 by 13.5 μ . Sporozoites piriform or comma-shaped, 8-13 by 3-4 μ with a mean of 11 by 4 μ .

Sporulation Time. Three to 4 days at 25-28 C in 2% potassium bichromate solution according to Svanbaev (1958, 1959).

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Capreolus capreolus* (roe deer).

Location. Oocysts in feces.

Geographic Distribution. USSR (Kazakhstan).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Svanbaev (1958) found this species in 3 roe deer.

***Isospora aksaica* Bazanova, 1952**

Description. Oocysts spherical, dark silver under low magnification and light pinkish gray under high, 26 μ in diameter. Oocyst wall 1.6 μ thick, smooth and double-contoured, with a light blue outer layer and a greenish, dingy rose inner layer. Micropyle presumably absent. Oocyst residuum presumably absent. Oocyst polar granules possibly present. Sporocysts ellipsoidal or spherical, 22 by 15 μ . Sporocyst residuum presumably absent. Sporozoites spherical, bean-shaped or ellipsoidal, 15 by 11 μ .

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bos taurus* (ox).

Location. Oocysts found in feces.

Geographic Distribution. USSR (Kazakhstan).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

Remarks. There is a question whether this is a valid species of bovine coccidium or a pseudoparasite. Levine and Mohan (1960), Levine (1961) and Pellérdy (1965) discussed this question; all were dubious about the validity of the species.

***Isospora* sp. Levine and Mohan, 1960**

(PLATE 60, FIG. 267)

? Isospora sp. Cooper and Gulati, 1926.

Description. Oocysts usually subspherical, occasionally spherical, 21-33 by 20-32 μ with a mean of 27 by 25 μ . Oocyst wall smooth, colorless, pale lavender or pale yellowish, composed of a single layer about 1 μ thick, sometimes apparently lined by a thin membrane. Micropyle absent. Oocyst residuum absent. Several irregular, refractile polar granules present. Sporocysts lemon-shaped, quite thick-walled, 14-20 by 10-12 μ with a mean of 17 by 11 μ . Sporocyst Stieda body a button-shaped cap, with a dependent globular, hyaline mass (substiedal body) protruding into the interior of the sporocyst. Sporocyst residuum finely granular. Sporozoites appear sausage-shaped, not arranged in any particular order in sporocyst. Sporocyst residuum and sporozoites enclosed in a membrane, forming more or less of a ball within the sporocyst.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Bos taurus* (ox); *Bos taurus*-*B. indicus* hybrids.

Other Hosts. Presumably *Bos indicus* (zebu) (See Cooper and Gulati, 1926, below).

Location. Oocysts found in feces.

Geographic Distribution. United States (Illinois), India (?).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Levine and Mohan (1960) found this form in 11% of 54 cattle on 3 farms in Illinois.

Remarks. Levine and Mohan (1960) found that this form was practically indistinguishable from *I. lacazei* of the English sparrow, and concluded that the oocysts they found in bovine feces might well be those of *I. lacazei*. Their calculations indicated that oocysts present in sparrow droppings might pass through a calf and be discovered in its feces if it ate a single fecal deposit from a single sparrow in the course of a day.

It is possible that the *Isospora* sp. reported from bovine feces in India by Cooper and Gulati (1926) might have been the same form as this, but their description was too meager for any conclusion to be drawn.

Isospora sp. Shah, 1963

(PLATE 60, FIG. 266)

Description. Oocyst usually subspherical, occasionally spherical, 20-25 by 20-24 μ with a mean of 23 by 22 μ . Oocyst wall composed of 2 layers, the outer one smooth, pale yellowish or pale yellowish brown and 1 μ thick, the inner one brownish yellow, 0.5 μ thick, forming a thin membrane. Micropyle and micropylar cap absent. Oocyst residuum absent. Oocyst polar granule ordinarily present. Sporocysts lemon-shaped, quite thick-walled. Stieda body in form of a button-shaped cap with a dependent hyaline mass extending into the interior of the sporocyst, 14-15 by 9-10 μ with a mean of 14 by 10 μ . Sporocyst residuum present as fine granules. Sporozoites more or less sausage-shaped, not arranged in any particular order in sporocyst. There appeared to be a membrane within the sporocysts which enclosed both the sporozoites and sporocyst residuum so that they formed more or less of a ball.

Sporulation Time. Unknown.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Ovis aries* (domestic sheep).

Location. Unknown. Oocysts found in feces.

Geographic Distribution. North America (Illinois).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Shah (1963) found this form in 1% of 153 sheep from Illinois and other states; the infected sheep came from Illinois.

Remarks. It is uncertain, as Shah (1963) said, whether this form is actually a genuine parasite of the sheep or a pseudoparasite; it resembles *I. lacazei* from the English sparrow and may have been a feed contaminant passing through the sheep.

GENUS *WENYONELLA* HOARE, 1933

In this genus, the oocyst has four sporocysts each containing four sporozoites.

Wenyonella markovi Grobov and Ven'-Shun', 1963

(PLATE 60, FIG. 268)

Description. Oocysts shaped like a round-bottomed urn, bright yellow or yellow gray, 31-46 by 21-31 μ with a mean of 39.4 by 25.2 μ . Oocyst wall composed of 2 layers, 1.5-2.3 μ thick with a mean of 1.7 μ ; outer layer thin, smooth, with fine stippling on its surface; inner layer thick, rough. Micropyle prominent at small end of oocyst. 4-6 μ in diameter with a mean of 5.0 μ . Oocyst polar granule and oocyst residuum absent. Sporocysts ellipsoidal, apparently without Stieda body, 9-12 by 8-12 μ with a mean of 11 by 10 μ . Sporocyst residuum absent. Sporozoites 5-6 by 5 μ with a mean of 5.2 by 4.7 μ . Each sporozoite contains a "polar granule."

Sporulation Time. According to Grobov and Ven'-Shun' (1963), the sporulation time in 2% potassium dichromate solution at room temperature (13-20 C) was 26-30 days.

Schizogony and Gametogony. Unknown.

Prepatent Period. Unknown.

Type Host. *Capreolus capreolus pygargus* (Siberian roe deer).

Location. Oocysts found in feces.

Geographic Distribution. USSR (Primorskiĭ region).

Pathogenicity. Unknown.

Cross-Transmission Studies. None.

Prevalence. Unknown.

DISCUSSION

In Tables 1 through 9 are summarized the known structural characters of the known species of coccidia from ruminants. Tables 1 through 8 give the characters of the species of *Eimeria*, arranged by host family or subfamily, while Table 9 gives the characters of the *Isospora* and *Wenyonella* species.

Number of Species of Ruminant Coccidia

A total of 100 named species of coccidia is included in this monograph. *Eimeria* is by far the most common genus, with 95 named species. In addition, 4 species of *Isospora* and one of *Wenyonella* have been named.

While this may seem quite a large number, it is, as in the rodent coccidia, only a small percentage of the number of species which must actually occur in ruminants. In Table 10 are listed the numbers of genera and species in each ruminant family together with the numbers of species of *Eimeria* which have been described from them. *Eimeria* has been described from only 30% of the 87 genera and 21% of the 188 species of ruminants. These figures may be compared with the 15% of 337 genera and 4% of the 2,688 species of rodents given for

176 species of *Eimeria* by Levine and Ivens (1965). (In an addendum they added 18 more named species of *Eimeria*, but did not include these in the percentages.)

Coccidia have been described from 5 of the 6 ruminant families; the single exception is the Giraffidae. Domestic animals loom large in the count. We are accepting as valid 5 species of *Eimeria* from *Camelus*, 3 from the alpaca, 5 from *Rangifer*, 16 from *Bos*, 17 from *Bubalus* (of which 12 were also reported from *Bos*), 13 from the domestic sheep *Ovis aries* (of which 10 were also reported from the domestic goat), and 12 from the domestic goat *Capra hircus* (of which 10 were also reported from the domestic sheep). Only 46 species of *Eimeria* have been described from only 29 (17%) of the 179 nondomestic ruminant species, whereas 49 species of *Eimeria* have been described from the 9 domestic species.

No coccidia have been described from the 5 species of *Tragul*us, the 6 of *Muntiacus*, the 5 of *Rusa*, or the 6 (or more) of *Cephalobus*. The African wild ruminants have been studied very little.

Relation of *Eimeria* Oocyst Structure to Host Family

In an attempt to determine whether there is any structural character or group of characters which might be used to differentiate the oocysts of *Eimeria* of one group of ruminants from those of another group (or to differentiate the oocysts of ruminant *Eimerias* from those of other host orders or classes), the known structural characters of the oocysts of *Eimeria* species were tabulated by host family or subfamily in Table 11.

In general, it can be said that the oocysts of ruminant *Eimeria* species usually lack an oocyst residuum (90%) but have a sporocyst residuum (84%), have a micropyle (72%) but lack a micropylar cap (77%), and have a sporocyst Stieda body (73%). An oocyst polar granule may (53%) or may not (47%) be present. On the whole, the *Eimeria* species in the Cervidae tend to lack an oocyst polar granule (73%), whereas those in the Bovidae tend to have one (60%). A micropylar cap is often present in the *Eimeria* species of the Caprinae (50%) whereas it is generally absent in the Bovinae (92%) and Cervidae (96%).

Levine and Ivens (1965) found that the species of *Eimeria* in rodents usually lack a micropyle (82%) and an oocyst residuum (65%), may or may not have an oocyst polar granule (57% have one) or a sporocyst Stieda body (60% have one) and usually have a sporocyst resid-

uum (89%). In general, then, ruminant *Eimeria* species may often be differentiated from rodent ones by their possession of a micropyle. In addition, only *E. disaensis* and *E. nachitschevanica* of rodents are known to have a micropylar cap, whereas 48% of the *Eimerias* of the Caprinae are known to have one. Aside from these, there are no noteworthy differences in distribution of characters between *Eimeria* species from rodents and ruminants. There is no evidence of parallel evolution between hosts and parasites which would differentiate the rodent from the ruminant coccidia. Perhaps the only evidence for parallel evolution has to do with the presence of a micropylar cap in many of the *Eimeria* species of the Caprinae. In general, however, the structural characteristics of the coccidian species in these two host orders have not changed progressively, but appear to have arisen more or less at random.

Cross-Infection Studies

The cross-infection experiments which we know to have been carried out with the coccidia from ruminants are summarized in Table 12; all were with *Eimeria*. Such experiments have been carried out with what the authors presumed to be about 27 species of *Eimeria* from 10 host genera and 13 host species. The great majority were with coccidia from the domestic goat and domestic sheep. To summarize, a total of 156 cross-infection experiments has been reported, of which 151 were from one ruminant species to another. None of the attempted cross-transmissions from ruminants to another order of mammals succeeded. There were 141 attempts at transmission from one host genus to another. Of these, 10 were said to have succeeded, and an eleventh may have succeeded. Those which were said to have succeeded, were the report of Subramanian and Jha (1966) of transmission of *E. ninakohlyakimovae* from the domestic goat to the domestic sheep, that of Fitzsimmons (1964) on the transmission of *E. ninakohlyakimovae* from the domestic sheep to the domestic goat, that of Subramanian and Jha (1966) on the transmission of *E. faurei* from the domestic goat to the domestic sheep, that of Fitzsimmons (1964) on the transmission of *E. faurei* from the domestic sheep to the domestic goat, that of Restani (1968) of *E. yakimoffmatschoulskyi* from *R. rupicapra* to the domestic sheep and domestic goat and that of Sayin (1969) of *E. ellipsoidalis*, *E. zuernii*, *E. bovis* and *E. auburnensis* from the water buffalo to the ox. The eleventh attempt, which may have been suc-

cessful, was the report of Deiana and Delitala (1953a) that they might have transmitted *E. arloingi* from the domestic goat to the domestic sheep. In opposition to these reported successes, 3 attempts to transmit *E. arloingi* from the domestic goat to the domestic sheep, 3 to transmit *E. ninakohlyakimovae* from the domestic goat to the domestic sheep, 4 to transmit *E. ninakohlyakimovae* from the domestic sheep to the domestic goat, 3 to transmit *E. faurei* from the domestic goat to the domestic sheep, 4 to transmit *E. faurei* from the domestic sheep to the domestic goat, 1 to transmit *E. intricata* from the domestic goat to the domestic sheep, 4 to transmit *E. intricata* from the domestic sheep to the domestic goat, 2 to transmit *E. parva* from the domestic goat to the domestic sheep, 3 to transmit *E. parva* from the domestic sheep to the domestic goat, 1 to transmit *E. granulosa* from the domestic sheep to the domestic goat, 1 to transmit *E. crandallis* from the domestic sheep to the domestic goat, 1 to transmit *E. ahsata* from the domestic sheep to the domestic goat, and 4 to transmit *E. ovina* from the domestic sheep to the domestic goat all failed. This was a total of 34 failures as against 4 reported successes and 1 reported possible success. Transmission between host genera of different families or even tribes probably does not occur. Whether it actually occurs between *Capra* and *Ovis*, which are in the same tribe, is still open to question. In this connection, 10 attempts to transmit *Eimeria* from one host species to another in the same genus (all by Svanbaev, 1967a) failed.

Surprisingly, few attempts have apparently been made to transmit coccidia between the ox, zebu, and water buffalo, although 12 species are presumed to be common to all 3 hosts.

Some authors have thought that wild and domestic ruminants have the same species of *Eimeria*. This is highly unlikely. Two of 46 attempts to transmit *Eimeria* from wild to domestic ruminants, and none of 27 attempts to transmit it from domestic to wild ruminants has succeeded; furthermore, the 2 "successes" (by Restani, 1968 of *E. yakimoffmatschoulskyi* from the chamois to a goat and a lamb) are suspect.

SUMMARY

This monograph summarizes the known information on taxonomy, structure, fine structure, life cycle, hosts, location in the host, pathogenicity, geographic distribution and cross-transmission studies of the 100 named species of coccidia of ruminants. These include 95 species of *Eimeria*, 4 of *Isospora* and one of *Wenyonella*. In addition, similar data are given for those forms for which insufficient information is available to justify assigning them names.

Eimeria, which is the commonest genus, has been described from 30% of the 87 genera and 21% of the 188 species of ruminants. The location in the host is known for 17 species of *Eimeria* (18% of those named), the endogenous stages are known for 15 species (16% of those named), and presumably complete life cycles have been worked out for only 2 species (*E. bovis* and *E. auburnensis*). Among the other coccidian genera, none of this information is known.

In general, the oocysts of ruminant *Eimeria* usually lack an oocyst residuum (90%) but have a sporocyst residuum (84%), have a micropyle (72%), lack a micropylar cap (77%) and have a sporocyst Stieda body (73%). A micropylar cap is often present in the *Eimeria* species of the Caprinae (50%) whereas it is generally absent in the Bovinae (92%) and Cervidae (96%).

Cross-infection experiments have been carried out with about 27

species of *Eimeria* from 13 donor host species. A total of 156 cross-infection experiments has been reported, of which 151 were from one ruminant species to another; most were with coccidia from the domestic goat and domestic sheep. Of the 141 attempts to transmit *Eimeria* from one host genus to another, 10 were said to have succeeded, and an eleventh may have succeeded. Five possible successes were with *E. ninakohlyakimovae*, *E. faurei* and perhaps *E. arloingi* between the domestic goat and domestic sheep. In opposition to these, however, 21 attempts to transmit these same forms between domestic goats and domestic sheep failed. Transmission between host genera of different families or even tribes probably does not occur. Whether it actually occurs between *Capra* and *Ovis*, which are in the same tribe, is still open to question. Although 12 species of *Eimeria* are thought to be common to the ox, zebu and water buffalo, few attempts have apparently been made to transmit any of them from one host to another. None of 37 attempts to transmit *Eimeria* from wild to domestic ruminants or of 27 attempts to transmit it from domestic to wild ruminants has succeeded. Two ostensible successes were with *E. yakimoffmatschoulskyi* from the chamois to a goat and a lamb, but this report is suspect.

The following are established as new species of *Eimeria*: *E. bactriani* n. sp. for the form described from the Bactrian camel *Camelus bactrianus* by Nöller (1933) and assigned by him and various other authors to *E. cameli*; *E. connochaetei* n. sp. for the form described from the gnu *Connochaetes gnu* by Prasad (1960) and assigned by him to *E. ellipsoidalis*; and *E. ovina* n. sp. for the form reported from the domestic sheep *Ovis aries* by various authors under the name *E. arloingi*.

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TABLE 1

EIMERIA OF RUMINANT FAMILY CAMELIDAE (SUPERFAMILY TYLOPODA)

Eimeria SPECIES	HOSTS	OOCYST CHARACTERS			SPOROCTYST CHARACTERS		
		SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	RESID- UUM
<i>bactriani</i>	<i>Camelus bactrianus</i> , <i>C. dromedarius</i>	spherical to short ellipsoidal	1 layer, light yellow- ish to yellowish brown	+	+	-	8-17 × 6-10 round or elongate
<i>cameli</i>	<i>Camelus dromedarius</i> , <i>C. bactrianus</i>	truncate ovoid, piriform	2-3 layers, 5-16 μ thick	+	+ or -	-	40-50 × 14.5-20; mean 45 × 18 elongate, pointed at both ends
<i>dromedarii</i>	<i>Camelus dromedarius</i> , <i>C. bactrianus</i>	ovoid, subspher- ical or spherical	2 (?) layers, brown	+	-	-	8-11 × 6-9 ovoid or spherical
<i>pellerdyi</i>	<i>Camelus bactrianus</i>	oval or ellip- soidal	2 layers, colorless, smooth	-	-	-	9-11 × 4-6 ovoid
<i>rajasthanii</i>	<i>Camelus dromedarius</i>	ellipsoidal	2 layers, outer light yellowish green, inner darker; 2-3 μ thick	+	-	-	14-15 × 8-11 ovoid
<i>peruviana</i>	<i>Lama glama</i>	ellipsoidal	1 (?) layer	-	-	+	10-15 × 7.5 ellipsoidal
<i>alpaca</i>	<i>Lama pacos</i>	ellipsoidal, rarely ovoid	2 layers, outer smooth, v. pale greenish to bluish, 1.1 μ thick; inner a dark yellow line, 0.4 μ thick	+	+	-	10-13 × 7-8 M 11 × 7 ovoid
<i>lamae</i>	<i>Lama pacos</i>	ellipsoidal, oc. ovoid	2 layers; outer smooth, bluish to greenish yellow, 1.3 μ thick; inner brownish yellow, 0.5 μ thick	+	+	-	13-16 × 8-10 M 15 × 8.5 Elongate ovoid
<i>punoensis</i>	<i>Lama pacos</i>	ellipsoidal, oc. ovoid	2 layers; outer smooth, blue to purplish, 0.7 μ thick; inner a dark line 0.3 μ thick	+	+	-	8-11 × 5-7 M 9 × 6 Somewhat elongate ovoid
							+
							v. small

TABLE 2
IMERIA OF RUMINANT SUBFAMILY CERVINAE (SUPERFAMILY CERVOIDEA; FAMILY CERVIDAE)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS				SPORO-CYST CHARACTERS				
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	SIZE (microns)	STEDIA BODY	RESID- UUM
<i>wassilevskiji</i>	<i>Aris aris</i>	29 × 28	Broadly ovoid	Double contoured, almost 3.6 μ thick	+	+				
<i>curvi</i>	<i>Cervus claphus</i>	33 × 21	Piriform		+			12 × 9 Ovoid		
<i>gallivervoi</i>	<i>Cervus claphus</i>	16-23 × 11-14	Ovoid				-	Piriform		
<i>asymmetrica</i>	<i>Cervus claphus</i>	25-33 × 15-19	Ellipsoidal, partially asymmetrical	Smooth, 1 layer colorless to yellowish	+	-	-	8-10 × 6-7 Ovoid	-	+
<i>austriaca</i>	<i>Cervus claphus</i>	17-25 × 14-20	Ellipsoidal to broadly ovoid	Smooth, 1 layer, colorless	-	-	-	10-13 × 5-6 Spindle-shaped	-	-
<i>robusta</i>	<i>Cervus claphus</i>	31-43 × 22-31	Ovoid	Rough, 2 layers, outer brown, inner colorless to yellowish, about 1 μ thick; total thick- ness 2-3 μ	+	+	-	14-19 × 7-10 Elongate ovoid	-	+
<i>sordida</i>	<i>Cervus claphus</i>	30-34 × 21-25	Ellipsoidal to ovoid	Rather rough, 1 layer, thick, yellowish to yellowish brown	+	+	-	12-13 × 7.5 Elongate ovoid		+
<i>schoenbuchi</i>	<i>Cervus claphus</i>	53-62 diam. M 59	Almost spherical	Wavy, sticky surface, 2 layers, 3-5 μ thick, brownish	-	-	+	27-28 long Elongate ovoid, later spindle-shaped		

TABLE 2 (cont.)
EIMERIA OF RUMINANT SUBFAMILY CERVINAE (CERVOIDEA; CERVIDAE)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS				SPOROCCYST CHARACTERS		
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	RESID- UUM
<i>elaphi</i>	<i>Cervus elaphus</i>	10-15 × 9-13 M 13 × 12	Spherical or subspherical	Smooth, 1 layer	-	-	-	+
sp. (?) Yakimoff, 1934	<i>Cervus elaphus</i>	21-30 × 18-24 M 28 × 21	Ovoid		-			
<i>hegneri</i>	<i>Cervus canadensis</i>	10-18 × 11-14	Ovoid		+			
					3.6 μ diam.			
<i>uapiti</i>	<i>Cervus canadensis</i>	32-42 × 24-29 M 38 × 26	Ovoid	Pitted, 1.5-2 μ thick, light yellowish brown	+	-	-	-
"zitrni"; "zurni";	<i>Cervus canadensis</i>	12-28 × 10-20	Spherical to subspherical		4 μ diam.			
sp. Yakimoff, 1935	<i>Sika hortulorum</i>	27 × 19-21	Ovoid		-			
spp. Ryšavý, 1954	<i>Dama dama</i>	see text						

TABLE 3

EIMERIA OF RUMINANT SUBFAMILY ODOCOILEINAE (SUPERFAMILY CERVOIDEA; FAMILY CERVIDAE)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS			SPOROCAST CHARACTERS					
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	STED- BODY	RESID- UUM	
TRIBE ODOCOILEINI										
<i>macdocksii</i>	<i>Odocoileus hemionus</i> , <i>O. virginianus</i>	33-37 × 25-29 M 35 × 27	ellipsoidal	2 layers, 1.1 μ in total thickness; outer smooth, deep yellowish brown	—	—	+	+	18-21 × 8-12 oblong ovoid	+
<i>odocoilei</i>	<i>Odocoileus hemionus</i> , <i>O. virginianus</i>	26-28 × 22-26 M 27 × 23.5	subspherical	1 layer, 1.3 μ thick, smooth, outer 2/3 colorless, inner 1/3 brownish yellow	—	+	—	+	13-15 × 8-10 M 14 × 9 ovoid	+
<i>ivenseae</i>	<i>Odocoileus hemionus</i>	30-37 × 18-22 M 32.5 × 21	ovoid, sl. piniform	2 layers; rough 1.5 μ thick; outer brown, 3/4 of wall thickness, inner light blue	+	+	—	+	14-18 × 6-9 M 16 × 7 elongate ovoid	+
<i>virginianus</i>	<i>Odocoileus virginianus</i>	42-55 × 26-42 M 49 × 33	elongate ovoid, ellipsoidal	2 layers, rough outer yellow brown, 3 μ thick; inner less than 1 μ thick	+	—	—	+	19-27 × 8-11 M 24 × 10 ellipsoidal	—
<i>madisonensis</i>	<i>Odocoileus virginianus</i>	14-19 × 13-16 M 16 × 15.5	spherical, subspherical	smooth, pale yellow, 2 layers	—	—	—	+	6-9 × 4-6 M 7.5 × 4.5 ellipsoidal	—
TRIBE RANGIFERINI										
<i>polaris</i>	<i>Rangifer tarandus</i>	24-34.5 × 15-21	ovoid, ellipsoidal or cylindroid	1 layer	+	+	—	—	no sporulated oocysts seen	—
<i>mayeri</i>	<i>Rangifer tarandus</i>	16-20 × 14-16 M 17 × 15	subspherical, seldom spherical	1 layer (?)	—	+	—	—	8-13 × 5.4 elongate ovoid, pointed at both ends	—
<i>muehlenis</i>	<i>Rangifer tarandus</i>	32-40 × 26-28 M 36 × 27	ovoid	2 layers 2 μ in total thickness; outer light yellowish; inner almost brown	+	—	—	+	16-20 × 8-10 ovoid	+

TABLE 3 (cont.)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS			SPOROCAST CHARACTERS			
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	RESID- UUM
<i>tarandina</i>	<i>Rangifer tarandus</i>	18-24 × 16-22 M 20 × 18	subspherical, sometimes spherical	1 layer (?)	-	-	-	12-14 × 6-8 elongate ovoid
<i>artica</i>	<i>Rangifer tarandus</i>	32-38 × 26-30 M 35.5 × 28	ovoid	1 layer (?), 1.0-1.2 μ thick, yellowish	+	-	-	12-14 × 7-9 ovoid
TRIBE CAPREOLINI								
<i>capreoli</i>	<i>Capreolus capreolus</i>	25-35 × 19-26 M 30 × 21 or M 24 × 13	ovoid or piriform	2 layers (?), smooth, yellowish, quite thick	+	-	-	13-16 × 6-10 elongate ovoid or 6 × 3 ovoid
<i>ponderosa</i>	<i>Capreolus capreolus</i>	38-45 × 25-29 M 40-41 × 26-28	piriform	2(?) layers 2.5 μ in total thickness, outer rough, yellowish brown, easily detached; inner transparent, 1 μ thick	+	-	-	19 × 9 ovoid
<i>rotunda</i>	<i>Capreolus capreolus</i>	11-14 diam. or 13-18 × 12-14	spherical, sometimes subspherical; spherical to ovoid	1 layer, smooth, colorless, thin	-	-?	-	6 diam. spherical (?)
<i>superba</i>	<i>Capreolus capreolus</i>	43-50 × 29-34 M 46 × 32	subellipsoidal, sl. ovoid	2 layers 3 μ thick; outer rough, dark brown; inner smooth, clear	+	-	-	16-21 × 10-12 elongate ovoid
<i>panda</i>	<i>Capreolus capreolus</i>	25-35 × 14-20	narrowly ovoid, sometimes bean-shaped	1 layer, smooth	+	-	-	13 × 7 elongate ovoid
sp. Boeh & Lucke, 1961	<i>Capreolus capreolus</i>	30-40 × 22-25	ellipsoidal	1 layer, smooth	+	-	-	-
spp. Ryšavý, 1954	<i>Capreolus capreolus</i>	No description — see text						

TABLE 4
EIMERIA OF RUMINANT FAMILY ANTILOCAPRIDAE (SUPERFAMILY BOVOIDEA)

<i>Eimeria</i> SPECIES	Hosts	OOCYST CHARACTERS				SPOROCCYST CHARACTERS				
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	SIZE (microns)	STED- BODY	RESID- UUM
<i>antilocaprae</i>	<i>Antilocapra americana</i>	25-35 × 21-30 M 31 × 26-27	ellipsoidal, broadly ellip- soidal or sub- spherical	2 layers, 2-2.2 μ thick; outer smooth, light yellow-green or blue; inner brown	-	+	+	16.5 × 9 or 13-17 × 8-11 M 15 × 9	+	+
sp. Todd, Hammond and O'Carra, 1967	<i>Antilocapra americana</i>	34-35 × 17-20	ovoid	2 layers, 2.5 μ in total thickness; outer rough	+	-	+	12-14 × 5-7	+	+

TABLE 5

EIMERIA OF RUMINANT SUBFAMILY BOVINAE (SUPERFAMILY BOVOIDEA; FAMILY BOVIDAE)

<i>Eimeria</i> SPECIES	Hosts	OOCYST CHARACTERS				SPOOROYST CHARACTERS				
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	SIZE (microns)	STYED- BODY	RESID- UUM
TRIBE STREPSICEROTINI										
<i>canna</i>	<i>Taurotragus</i> <i>oryx</i>	23-34 × 16-20	ovoid to almost ellipsoidal	3 layers; outer v. delicate; middle greenish and hyaline, 1 μ thick; inner a delicate membrane 0.5 μ from middle layer	+	- +	- +	12-17 × 5-7 ovoid	+	+
<i>triflittae</i>	<i>Taurotragus</i> <i>oryx</i>	21-24 × 15-19 M 21 × 18	ellipsoidal	1 layer	-	-	-	9 × 4-6 elongate with rounded ends		
TRIBE BOSELAPHINI										
<i>yakimovi</i>	<i>Boselaphus</i> <i>tragocamelus</i>	32-41 × 22-29	ovoid		+	-?	-	14-19 × 9? ovoid	-?	-
TRIBE BOVINI										
<i>azerbaid- schanica</i>	<i>Bubalus bubalis</i> 45 × 22		cylindrical, but with 1 side some- what concave and the other some- what convex		-					
<i>thianethi</i>	<i>Bubalus bubalis</i> ; <i>Bos taurus</i> ; <i>Bos indicus</i>	34-49 × 26-34 M 43 × 29	ovoid	2 layers 2 μ thick; outer thin, homo- geneous; inner thick, with transverse striations	+		-	22 × 9.5 lemon-shaped	-	+
<i>gokaki</i>	<i>Bubalus bubalis</i>	22-31 × 18-25	ovoid	thin, homogeneous, sl. yellowish brown	+	capped		elongate		+

TABLE 5 (cont.)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS				SPOROCYST CHARACTERS		
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	RESID- UUM
<i>ovoidalis</i>	<i>Bubalus bubalis</i>	32-40 × 20-28 M 35 × 24	ovoid	pinkish orange	+	-	-	14-16 × 8-9 ovoid
<i>bareillyi</i>	<i>Bubalus bubalis</i>	26-35 × 19-25 M 31 × 22	piriform	smooth, homogeneous, yellowish to darkish brown, 1 μ thick, lined by membrane	+	-	+	18 × 8 lemon-shaped
<i>ankarensis</i>	<i>Bubalus bubalis</i>	32-43 × 25-29 M 39 × 26	elongate ovoid	rough, yellowish brown, 2 layers lined by membrane, 3.0-3.5 μ thick	+	-	+	18-23 × 8-10 M 21 × 9 elongate, almost ellipsoidal
<i>zuernei</i>	<i>Bos taurus</i> ; <i>Bos indicus</i> ; <i>Bubalus bubalis</i> 14-17	12-29 × 10-21 M 17-20 × 14-17	subspherical, subovoid, ovoid, some- times ellipsoidal	1 layer 0.7 μ thick, smooth, colorless	-	+	+	8-13 × 4-7 M 9-11 × 5 elongate ovoid
<i>bovis</i>	<i>Bos taurus</i> ; <i>Bos</i> <i>indicus</i> ; <i>Bubalus</i> <i>bubalis</i> ; <i>Bison</i> <i>bonasus</i> (?); <i>Bibos banteng</i> (?)	23-34 × 17-23 M 27-28 × 20-21	ovoid, sub- ellipsoidal	2 layers; outer smooth, rarely roughened, 1.3 μ thick, colorless; inner brownish yellow 0.4 μ thick	+	-	+	13-18 × 5-8 M 15-16 × 7 elongate ovoid
<i>canadensis</i>	<i>Bos taurus</i> ; <i>Bos</i> <i>indicus</i> ; <i>Bison</i> <i>bonasus</i> (?); <i>Bibos banteng</i> (?); <i>Bubalus bubalis</i>	28-38 × 20-29 M 33 × 23-24	sl. ovoid or ellipsoidal	2 layers, outer colorless to yellowish, smooth, sometimes roughened, 0.5 μ thick; inner clear yellow, 1.3 μ thick; lined by thin membrane	+	-	+	15-22 × 6-9 M 18 × 8 elongate ovoid

TABLE 5 (cont.)

Eimeria SPECIES	HOSTS	OOCYST CHARACTERS					SPOROZOYTE CHARACTERS			
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	SIZE (microns)	STYED BODY	RESID- UUM
<i>ellipsoidalis</i>	<i>Bos taurus</i> ; <i>Bos indicus</i> ; <i>Bubalus bubalis</i> ; <i>Bison bonasus</i> (?); <i>Bibos banteng</i> (?); <i>Bibos gaurus</i> (?)	12-32 × 10-29	ellipsoidal to v. sl. ovoid	1 (2?) layer; 0.8 μ thick; lined by membrane; smooth, colorless	-	-	-	11-16 × 5-6 M 13-14 × 5 elongate ovoid	+	+
<i>cylindrica</i>	<i>Bos taurus</i> ; <i>Bos indicus</i> ; <i>Bubalus bubalis</i>	16-30 × 12-17 M 21-25 × 13-15	elongate ellipsoidal	1 layer 1.2 μ thick; colorless, smooth	-?	+	-	12-16 × 4-6 M 14 × 5 elongate ellipsoidal	-	+
<i>auburnensis</i>	<i>Bos taurus</i> ; <i>Bos indicus</i> ; <i>Bubalus bubalis</i>	32-46 × 19-28 M 36-41 × 22-26	elongate ovoid	1 layer (2?) 1.0-1.8 μ thick, lined by membrane; brownish yellow; smooth, rarely rough or heavily mammillated	+	+	-	16-23 × 7-11 M 18-19 × 8-9 elongate	+	+
<i>brasiliensis</i>	<i>Bos taurus</i> ; <i>Bos indicus</i> ; <i>Bubalus bubalis</i>	31-49 × 21-33 M 36-38 × 25-27	ellipsoidal	1 layer 1.8 μ thick, lined by brownish membrane; brownish yellow, generally smooth, oc. covered by plaques	+	+	-	16-22 × 7-10 elongate ellipsoidal	-	+
<i>alabamensis</i>	<i>Bos taurus</i> ; <i>Bos indicus</i> ; <i>Bubalus bubalis</i>	13-25 × 11-17	ovoid	1 layer 0.6-0.7 μ thick, lined by thin membrane; smooth, v. pale yellow	-	+	-	11-16 × 4-5 M 12 × 5 elongate	+	-
<i>subspicaria</i>	<i>Bos taurus</i> ; <i>Bos indicus</i> ; <i>Bubalus bubalis</i>	9-14 × 8-13 M 11-13 × 10-12	spherical to subspherical	1 layer 0.5-0.6 μ thick; smooth, pale yellowish	-	-	-	7-10 × 3-4 M 8 × 3.5 elongate ovoid	+	+

TABLE 5 (cont.)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS				SPOOROOCYST CHARACTERS		
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	RESID- UUM
<i>wyomingensis</i>	<i>Bos taurus</i> ; <i>Bos indicus</i> ; <i>Bubalus bubalis</i>	36-46 × 26-32 M 40 × 28	ovoid	1 layer 2.0-3.5 μ thick, lined by membrane; yellowish brown to brownish yellow, speckled and somewhat rough	+	-	18 × 9 ellipsoidal	- +
<i>pellita</i>	<i>Bos taurus</i>	36-41 × 26-30	ovoid	thick, dark brown, w. many small protuberances giving wall velvety appearance	+	-	14-18 × 6-8 elongate ovoid	+
<i>illinoensis</i>	<i>Bos taurus</i>	24-29 × 19-22 M 26 × 21	ellipsoidal or sl. ovoid	1 layer 1.3 μ thick, w. pale tan inner surface; smooth, colorless	-	-	13-16 × 6-7 M 15 × 6.5 elongate ovoid	+
<i>bukidnonensis</i>	<i>Bos indicus</i> ; <i>Bos taurus</i> ; <i>Bubalus bubalis</i> (?)	43-54 × 29-39	piriform	1 layer 3-4 μ thick, lined by membrane; yellowish brown, punctate, radially striated	+	-	20 × 10 elongate	- +
<i>bombayensis</i>	<i>Bos indicus</i>	32-40 × 20-25 M 37 × 22	ellipsoidal	1.0-1.5 μ thick; smooth, transparent, pale yellowish brown	+	?	12-15 long ovoid	+
<i>mundaragi</i>	<i>Bos indicus</i>	36-38 × 25-28	ovoid	0.3 μ thick, smooth, transparent, pale yellow or yellow	+	-	15-9 long ovoid	+
sp. Rastegaieff, 1929	<i>Bison bison</i>	16-29 × 14-21	ovoid	1.8 μ thick	+	-?	13.5 × 7 piriform	-

TABLE 6

EIMERIA OF RUMINANT SUBFAMILY HIPOTRAGINAE (SUPERFAMILY BOVOIDEA; FAMILY BOVIDAE)

<i>Eimeria</i> SPECIES	Hosts	OOCYST CHARACTERS			SPOROZOYTE CHARACTERS			
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	RESID- UUM
TRIBE REDUNCINI								
<i>macdli</i>	<i>Kobus ellipsi- pygmaeus</i>	24-34 × 20-24 M 30 × 21	ovoid	double contoured, radially striated, 1.5 μ thick	+	-	-	+
TRIBE ALCELAPHINI								
<i>talboti</i>	<i>Alcelaphus cokeri</i>	35-38 × 22-28 M 36 × 25	ovoid, asym- metrical	smooth, 1(2') layers, yellowish	-	-	-	-
sp. Prasad and Narayan, 1963	<i>Alcelaphus cokeri</i>	22-28 × 19-20 M 25 × 19	ellipsoidal	2 layers, outer sl. thicker than inner, colorless	-	+	-	+
<i>connochaei</i>	<i>Connochaetes gnu</i>	20-27 × 13-15 M 22 × 14	ellipsoidal	2 layers, smooth, pale yellow	-	-	-	+
<i>gorgonis</i>	<i>Gorgon taurinus</i>	20.5-26 × 15-18 M 23 × 16.5	ellipsoidal	2 layers, outer pale yellow and sl. thicker than inner, inner colorless; smooth	-	+	-	+

TABLE 8

EIMERIA OF RUMINANT SUBFAMILY CAPRINAE (SUPERFAMILY BOVOIDEA; FAMILY BOVIDAE)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS			SPORO-CYST CHARACTERS				
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	STEDIA BODY	RESID- UUM
TRIBE SAIGINI									
<i>sajanica</i>	<i>Saiga tatarica</i>	18-23 × 16.5-20 M 20 × 18	ovoid or spherical	double-contoured, up to 1 μ thick, colorless	—	—	—	5-10 × 3-5 ovoid	+
<i>saiga</i>	<i>Saiga tatarica</i>	27-32 × 28-34 M 29.5 × 30.5	spherical, rarely short oval	double-contoured, 1-1.4 μ thick, yellowish green or yellowish brown, smooth	—	+	+	7-12 × 7-9 M 10 × 8 spherical or short oval	+
spp. Svan- baev, 1958	<i>Saiga tatarica</i>	No descriptions—see text under <i>E. elegans</i> , <i>E. faurei</i> , <i>E. ninakohlyakimovae</i>							
TRIBE RUPICAPRINI									
<i>rupicaprae</i>	<i>Rupicapra rupicapra</i>	18-32.5 × 13-27	ovoid	double-contoured, 1 μ thick, smooth, yellowish	+	—	—	6-13 × 3-8 oval	+
<i>riedmuelleri</i>	<i>Rupicapra rupicapra</i>	15-23 × 14-22	spherical, ovoid or ellipsoidal	1 layer, 1-2 μ thick, pale yellow	—	—	—	6-13 × 6-8 ovoid to spherical	—
<i>yakimoffmal- schoulskyi</i>	<i>Rupicapra rupicapra</i>	23-36.5 × 18-26	ellipsoidal or ovoid	1 layer, 1-1.5 μ thick, yellowish	+	—	—	8-12.5 × 6-9 ovoid	+
<i>alpina</i>	<i>Rupicapra rupicapra</i>	10-14	spherical	1 layer, very thin, colorless, smooth	—	—	—	5-6 × 4-5.5 subspherical	—
<i>suppereri</i>	<i>Rupicapra rupicapra</i>	43-49 × 32-37 M 45 × 34	ellipsoidal	2 layers, outer 1.5-2.0 μ thick, rough, brown; inner layer colorless to yellowish, c. 1 μ thick	+	+	—	16-19 × 9-11 drop-shaped	+

TABLE 8 (cont.)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS				SPOROCAST CHARACTERS				
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	SIZE (microns)	STIEDE BODY	RESID- UUM
No descriptions—see text under <i>E. arloingi</i> , <i>E. crandallis</i> , <i>E. ninakolliyakimovae</i> , <i>E. parva</i>										
<i>orcanni</i> ssp. Ryšavý, 1954 <i>Rupicapra rupicapra</i>	<i>Orcannos americanus</i>	26-34 × 17-20 M 29 × 19	elongate ovoid, sl. pyriform	2 layers, outer smooth, yellowish, 1 μ thick; inner brownish-yellow, 0.4 μ thick; membrane lining wall	+	+	—	10-12 × 7-9 M 11 × 8 broadly ovoid	+	+
<i>montanacensis</i>	<i>Orcannos americanus</i>	15-23 × 13-19 M 19 × 15	subspherical to ellipsoidal, flattened at micropylar end	2 layers about 1.5- 2.0 μ thick; outer pale, about 2/3 of total thickness; inner light brown	+	+	—	8-12 × 4-7 M 10 × 5 ovoid	+	+
<i>crnsi</i>	<i>Orcannos americanus</i>	28-37 × 19-25 M 33 × 23	ellipsoidal	2 layers and inner membrane c. 1.8-2.3 μ thick; outer smooth, light brown, 3/4 of total thickness; inner dark brown	+	+	—	14-20 × 6-9 M 17 × 7	+	+
TRIBE CAPRINI										
<i>arloingi</i>	<i>Capra hircus</i> , <i>C. acaprus</i> , <i>C.</i> <i>falconeri</i> , <i>C.</i> <i>iber</i> , <i>C. sibirica</i>	22-36 × 16-26 M 28 × 19-21	ellipsoidal or sl. ovoid	2 layers, outer smooth, colorless, 1 μ thick; inner brownish yellow, 0.4-0.5 μ thick; lined by membrane	+	+	—	11-17 × 6-10 M 13-15 × 7-8 elongate ovoid	— or vestig.	+
<i>ninakolliya- kimovae</i>	<i>Capra hircus</i> , <i>C. acaprus</i> , <i>C.</i> <i>iber</i> , <i>C. sibirica</i> , <i>Ovis aries</i> , <i>O.</i> <i>canadensis</i> , <i>O.</i> <i>musimon</i> , <i>O.</i> <i>ammon</i>	19-28 × 14-23	ellipsoidal to somewhat ovoid	2 layers, outer smooth, colorless to sl. yellowish, 1 μ thick; inner yellowish brown, 0.4 μ thick	+	+	—	9-14 × 4-10 elongate ovoid	+	+

TABLE 8 (cont.)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS				SPORO-CYST CHARACTERS				
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	SIZE (microns)	STEDA BODY	RESID- UUM
<i>christenseni</i>	<i>Capra hircus</i>	32-44 × 22-30 M 38-39 × 25-26	ovoid, some- times ellipsoidal	2 layers, outer smooth, colorless to v. pale yellowish, 1 μ thick; inner brownish yellow, 0.4 μ thick; inner layer a mem- brane, usually wrinkled at micropyle end	+	+	-	14-18 × 8-11 M 15-16 × 9-10 broadly ovoid	- or vestig.	+
<i>ibicis</i>	<i>Capra ibex</i>	27 × 18	ovoid	smooth, bright rose	+		-			
<i>faurei</i>	<i>Ovis aries</i> , <i>O.</i> <i>canadensis</i> , <i>O.</i> <i>ammon</i> , <i>O.</i> <i>musimon</i> , <i>O.</i> <i>orientalis</i> , <i>Capra</i> <i>hircus</i> , <i>C. ibex</i> , <i>C. sibirica</i>	25-37 × 18-28	ovoid	1 layer, smooth, 1.3-1.8 μ thick, lined by membrane	+	+	-	11-17 × 7-9 M 14-15 × 8 broadly ovoid, ovoid or piriform	- or vestig.	+
<i>intricata</i>	<i>Ovis aries</i> , <i>O.</i> <i>canadensis</i> , <i>O.</i> <i>musimon</i> , <i>O.</i> <i>ammon</i> , <i>Capra</i> <i>hircus</i>	39-59 × 27-47	ellipsoidal or sl. ovoid	2 layers; outer irregular, granular, brownish yellow to dark brown, 2-3 μ thick, transversely striated; inner dark brown, 0.4-0.8 μ thick, lined by membrane	+	+	-	17-22 × 9-14 M 20 × 11-14 elongate ovoid	- or vestig.	+
<i>parva</i>	<i>Ovis aries</i> , <i>O.</i> <i>orientalis</i> , <i>O.</i> <i>ammon</i> , <i>O.</i> <i>musimon</i> , <i>O.</i> <i>canadensis</i> , <i>Capra hircus</i> , <i>C.</i> <i>sibirica</i> , <i>C. ibex</i>	12-23 × 10-19	subspherical, ovoid, ellip- soidal or spherical	2 layers, outer smooth, pale to brownish yellow, 0.8-1.2 μ thick; inner a dark, thin membrane	+	+	-	6-13 × 5-8 ovoid to elongate ovoid	- or small	+

TABLE 8 (cont.)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS				SPORO-CYST CHARACTERS				
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	SIZE (microns)	STIEDE BODY	RESID- UUM
<i>gilvuthi</i>	<i>Ovis aries</i> , <i>Capra hircus</i> , <i>Pseudois nathoor</i>	unknown	unknown	unknown Named from selizonts; relationship to other coccidia unknown.	unknown	unknown	unknown	unknown	unknown	unknown
<i>granulosa</i>	<i>Ovis aries</i> , <i>O.</i> <i>canadensis</i> , <i>Capra hircus</i>	22-35 × 17-25	piriform, ellipsoidal or urn-shaped	2 layers; outer smooth, pale yellow- ish, 0.4-0.6 μ thick; inner brownish yellow, 0.8 μ thick; lined by membrane	+	+	-	13-16 × 8-9 M 15 × 8 ovoid or elongate ovoid	+	+
<i>pallida</i>	<i>Ovis aries</i> , <i>Capra hircus</i> , <i>C. ibex</i>	12-20 × 8-15	ellipsoidal	2 layers 0.5 μ in total thickness; outer smooth, colorless to pale yellowish; inner a dark line on inner surface of wall	-	+	-	6-9 × 4-6 elongate ovoid	-	+
<i>hawkinsi</i>	<i>Ovis aries</i> , <i>Capra hircus</i>	20-25 × 15-23	spherical to subspherical	1 layer (?), smooth, light grayish pink pointed cap (?)	+	+	-	10-15 × 7-10 M 11 × 8 piriform	-	+
<i>punctata</i>	<i>Ovis aries</i> , <i>Capra hircus</i>	18-28 × 16-21	ellipsoidal or subspherical to ovoid	2 layers; outer punctate, colorless to yellowish, 1.4 μ thick; inner greenish to brownish yellow, 0.4 μ thick	+	+	+	12-15 × 7-9 elongate ovoid, spherical, ellipsoidal or piriform	+	+
<i>ovina</i>	<i>Ovis aries</i> , <i>O.</i> <i>canadensis</i> , <i>O.</i> <i>ammon</i> , <i>O.</i> <i>musimon</i>	23-36 × 16-24	ellipsoidal to ovoid, generally with rather straight sides	2 layers; outer smooth, oc. rough, greenish to yellowish brown, 1.3 μ thick; inner a brownish yellow membrane 0.5 μ thick	+	+	-	11-17 × 6-9 elongate ovoid	- or vestig.	+

TABLE 8 (cont.)

<i>Eimeria</i> SPECIES	HOSTS	OOCYST CHARACTERS			SPORO-CYST CHARACTERS			
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	STEDA BODY
<i>gonzalezi</i>	<i>Ovis arcticus</i>	26-38 × 18-26 M 24 × 19	ovoid, ellipsoidal	2 layers, outer transparent, inner yellowish brown, total thickness 1.8 μ	+	+	-	12-15 × 6-9 M 14 × 8 ovoid
sp. Mincheva et al., 1966	<i>Ovis arcticus</i>	10 × 6-10	spherical to ellipsoidal	thick, smooth, colorless	+			spherical
<i>alsata</i>	<i>Ovis canadensis</i> , <i>O. arcticus</i> , <i>O.</i> <i>musimon</i> , <i>Capra</i> (?)	29-44 × 17-30	ellipsoidal to somewhat ovoid	2 layers 0.9-1.3 μ in total thickness; lavender to yellowish to light brown; outer smooth; inner a dark membrane	+	+	-	12-22 × 6-10 elongate ovoid
<i>crandallii</i>	<i>Ovis canadensis</i> , <i>O. arcticus</i> , <i>O.</i> <i>musimon</i> , <i>O.</i> <i>ammon</i> , <i>Capra</i> <i>hirca</i> , <i>C. sibirica</i> , <i>C. acgagrus</i>	17-28 × 14-22	ellipsoidal to subspherical	2 layers; outer color- less, 0.9-1.3 μ thick; inner a darkish yellow membrane	+	+	-	8-13 × 5-9 ovoid
<i>arkhara</i>	<i>Ovis vignei</i> , <i>O.</i> <i>ammon</i>	20-24 × 18-20 M 22 × 17	ellipsoidal, often ovoid	1 layer, yellowish, up to 1 μ thick	-	-	-	6-8 × 6 ellipsoidal

oc. vestig.

+

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TABLE 9
ISOSPORA AND WENYONELLA OF RUMINANTS

Isospora SPECIES	HOSTS	OOCYST CHARACTERS				SPOROOCYST CHARACTERS				
		SIZE (microns)	SHAPE	WALL	MICRO- PYLE	POLAR GRANULE	RESID- UUM	SIZE (microns)	STEDIA BODY	RESID- UUM
<i>ortovi</i>	"Camel"	27-35 × 15-20	ellipsoidal, ovoid, piriform, cylindrical or figure 8-shaped	2 layers (illus. as 1 layer) 1 μ thick; outer greenish; inner reddish or brown	-	-	-	15-20 × 13-17 ellipsoidal, ovoid 13.5-15 diam. spherical	-	+
<i>rangiferis</i>	<i>Rangifer tarandus</i>	26-32 × 24-30 M 29 × 24.5	ovoid, sub- spherical	1 layer	-	+	-	12-19(?) × 8-12 ovoid	+	+
<i>capreoli</i>	<i>Capreolus capreolus</i>	40-46 × 28-32 M 43 × 31	ovoid, piriform	2 layers 2-4 μ thick; yellowish brown or brown, inner layer radially striated	+	-	+	19-25 × 11-16 M 22 × 13.5 piriform, ovoid	-	-?
<i>akseita</i>	<i>Bos taurus</i>	26 diam.	spherical	2 layers, 1.6 μ thick; outer light blue; inner greenish, dingy rose	-?	+	-?	22 × 15 ellipsoidal or spherical	-	-?
sp. Levine and Mohan, 1960	<i>Bos taurus</i>	21-33 × 20-32 M 27 × 25	subspherical	1 layer 1 μ thick, smooth, colorless to pale yellowish or pale lavender	-	+	-	14-20 × 10-12 M 17 × 11 lemon-shaped	+	+
sp. Shah, 1963	<i>Ovis arcticus</i>	20-25 × 20-24 M 23 × 22	subspherical	2 layers: outer 1 μ thick, smooth, pale yellowish or pale yellowish brown; inner 0.5 μ thick, brownish yellow	-	+	-	14-15 × 9-10 M 14 × 10 lemon-shaped	+	+
<i>markovi</i>	<i>Capreolus capreolus pugargus</i>	31-46 × 21-31 M 39 × 25	like round- bottomed urn	2 layers 1.5-2.3 μ in total thickness; outer thin, smooth, stippled; inner thick, rough	+	-	-	9-12 × 8-12 M 11 × 10 ellipsoidal	-?	-
<i>Wenyonella</i> SPECIES										

Wenyonella
SPECIES

TABLE 10
NAMED SPECIES OF *EIMERIA* IN RUMINANTS

RUMINANT FAMILY*	No. RUMINANT GENERA	No. RUMINANT SPECIES	No. <i>EIMERIA</i> SPECIES DESCRIBED	RUMINANT GENERA FROM WHICH <i>EIMERIA</i> HAS BEEN DESCRIBED		RUMINANT SPECIES FROM WHICH <i>EIMERIA</i> HAS BEEN DESCRIBED	
				No.	PERCENT	No.	PERCENT
Camelidae	2	6	9	2	100	4	67
Tragulidae	2	6	0	0	0	0	0
Cervidae	22	42	25	5	23	7	17
(Subf. Moschinae)	(1)	(1)	(0)	(0)	(0)	(0)	(0)
(Subf. Muntiacinae)	(2)	(7)	(0)	(0)	(0)	(0)	(0)
(Subf. Cervinae)	(8)	(20)	(11)	(2)	(25)	(3)	(15)
(Subf. Odocoileinae)	(11)	(14)	(12)	(3)	(27)	(3)	(21)
(Tribe Odocoileini)	(7)	(10)	(5)	(1)	(14)	(2)	(20)
(Tribe Aleini)	(1)	(1)	(0)	(0)	(0)	(0)	(0)
(Tribe Rangiferini)	(1)	(1)	(5)	(1)	(100)	(1)	(100)
(Tribe Hydropotini)	(1)	(1)	(0)	(0)	(0)	(0)	(0)
(Tribe Capreolini)	(1)	(1)	(5)	(1)	(100)	(1)	(100)
Giraffidae	2	2	0	0	0	0	0
(Subf. Palaeotraginae)	(1)	(1)	(0)	(0)	(0)	(0)	(0)
(Subf. Giraffinae)	(1)	(1)	(0)	(0)	(0)	(0)	(0)
Antilocapridae	1	1	1	1	100	1	100

TABLE 10 (cont.)

RUMINANT FAMILY*	No. RUMINANT GENERA	No. RUMINANT SPECIES	No. <i>EIMERIA</i> SPECIES DESCRIBED	RUMINANT GENERA FROM WHICH <i>EIMERIA</i> HAS BEEN DESCRIBED		RUMINANT SPECIES FROM WHICH <i>EIMERIA</i> HAS BEEN DESCRIBED	
				No.	PERCENT	No.	PERCENT
Bovidae	58	131	55	17	29	27	21
(Subf. Bovinae)	(14)	(23)	(23)	(4)	(29)	(5)	(22)
(Tribe Strepsicerotini)	(5)	(9)	(2)	(1)	(20)	(1)	(5)
(Tribe Boselaphini)	(2)	(2)	(1)	(1)	(50)	(1)	(50)
(Tribe Bovini)	(7)	(12)	(21)	(2)	(29)	(3)	(25)
(Subf. Cephalophinae)	(3)	(11)	(10)	(0)	(0)	(0)	(0)
(Subf. Hippotraginae)	(13)	(31)	(4)	(4)	(31)	(4)	(13)
(Tribe Reduncini)	(5)	(11)	(1)	(1)	(20)	(1)	(9)
(Tribe Hippotragini)	(3)	(8)	(0)	(0)	(0)	(0)	(0)
(Tribe Alcelaphini)	(5)	(12)	(3)	(3)	(60)	(3)	(25)
(Subf. Antilopinae)	(15)	(35)	(4)	(4)	(27)	(4)	(11)
(Tribe Neotragini)	(8)	(18)	(0)	(0)	(0)	(0)	(0)
(Tribe Antilopini)	(7)	(17)	(4)	(4)	(57)	(4)	(24)
(Subf. Caprinae)	(13)	(31)	(26)	(6)	(46)	(15)	(48)
(Tribe Saigini)	(2)	(2)	(2)	(1)	(50)	(1)	(50)
(Tribe Rupicapriini)	(4)	(7)	(8)	(2)	(50)	(2)	(29)
(Tribe Ovisovini)	(2)	(2)	(0)	(0)	(0)	(0)	(0)
(Tribe Caprini)	(5)	(20)	(17)	(3)	(60)	(12)	(60)
TOTAL	87	188	95	26	30	40	21

* Based on Simpson (1945)

TABLE 11

STRUCTURAL CHARACTERS OF OOCYSTS OF *EIMERIA* SPECIES FROM DIFFERENT RUMINANT FAMILIES

RUMINANT FAMILY OR SUBFAMILY	NUMBERS OF EIMERIA SPECIES WITH OR WITHOUT DESIGNATED CHARACTERS											
	MICROPYLE	POLAR GRANULE		OOCYST RESIDIUM		STIEDA BODY	SPORO-CYST RESIDIUM		MICROPYLAR CAP			
		+	-	+	-		+	-	+	-		
Camelidae	7	2	5	4	1	8	5	3	7	1	5	4
Tragulidae	0	0	0	0	0	0	0	0	0	0	0	0
Cervidae	17	8	6	14	2	20	9	5	15	5	1	24
Moschinae	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Muntiacinae	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Cervinae	(7)	(3)	(2)	(5)	(1)	(7)	(0)	(3)	(4)	(2)	(1)	(9)
Odocoileinae	(10)	(5)	(4)	(9)	(0)	(14)	(9)	(2)	(11)	(3)	(0)	(15)
Giraffidae	0	0	0	0	0	0	0	0	0	0	0	0
Antilocapridae	0	1	1	0	1	0	1	0	1	0	0	1
Bovidae	40	14	28	19	6	50	29	8	47	7	15	43
Bovinae	(16)	(6)	(8)	(9)	(4)	(18)	(15)	(4)	(19)	(2)	(2)	(23)
Cephalophinae	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Hippotraginae	(1)	(3)	(1)	(3)	(0)	(4)	(1)	(1)	(3)	(1)	(0)	(4)
Antilopinae	(4)	(0)	(1)	(2)	(0)	(4)	(1)	(0)	(3)	(1)	(0)	(3)
Caprinae	(19)	(5)	(18)	(5)	(2)	(24)	(13)	(3)	(22)	(3)	(13)	(13)
TOTAL	64	25	40	36	9	79	44	16	70	13	21	72
PERCENT OF TOTAL FOR EACH CHARACTER												
	72	28	53	47	10	90	73	27	84	16	23	77

TABLE 12
SUMMARY OF CROSS-INFECTION EXPERIMENTS WITH *EIMERIA* IN RUMINANTS

<i>EIMERIA</i> SPECIES	DONOR HOST	RECEPTOR HOST	RESULT	REFERENCE
<i>austriaca</i>	<i>Cervus elaphus</i>	<i>Bos taurus</i> <i>Ovis aries</i> <i>Capra hircus</i>	— — —	Supperer & Kutzer, 1961
<i>robusta</i>	<i>Cervus elaphus</i>	<i>Bos taurus</i> <i>Ovis aries</i> <i>Capra hircus</i>	— — —	Supperer & Kutzer, 1961
<i>capreoli</i> ?	<i>Capreolus capreolus</i>	<i>Ovis aries</i> <i>Saiga tatarica</i>	— —	Svanbaev, 1967a
<i>yakimofmutschowskii</i>	<i>Rupicapra rupicapra</i>	<i>Ovis aries</i> <i>Ovis aries</i> <i>Capra hircus</i>	— — —	Supperer & Kutzer, 1961 Kutzer, 1964
	<i>Rupicapra rupicapra</i>	<i>Ovis aries</i> <i>Capra hircus</i> <i>Bos taurus</i>	+ + —	Supperer & Kutzer, 1961 Restani, 1968 Restani, 1968 Restani, 1968
<i>alpina</i>	<i>Rupicapra rupicapra</i>	<i>Ovis aries</i>	—	Kutzer, 1964
<i>suppereri</i>	<i>Rupicapra rupicapra</i>	<i>Ovis aries</i>	—	Kutzer, 1964
<i>rupicaprae</i>	<i>Rupicapra rupicapra</i>	<i>Ovis aries</i> <i>Capra hircus</i> <i>Bos taurus</i>	— — —	Restani, 1968 Restani, 1968 Restani, 1968
<i>riedmuelleri</i>	<i>Rupicapra rupicapra</i>	<i>Ovis aries</i> <i>Capra hircus</i> <i>Bos taurus</i>	— — —	Restani, 1968 Restani, 1968 Restani, 1968

TABLE 12 (cont.)

IMERIA SPECIES	DONOR HOST	RECEPTOR HOST	RESULT	REFERENCE
<i>antilocervi</i>	<i>Antelope cervicapra</i>	<i>Bos indicus</i> (?)	-	Ray & Mandal, 1960
<i>ankarensis</i>	<i>Bubalus bubalis</i>	<i>Bos taurus</i>	-	Sayin, 1969
<i>ellipsoidalis</i>	<i>Bubalus bubalis</i>	<i>Bos taurus</i>	+	Sayin, 1969
<i>zuernii</i>	<i>Bubalus bubalis</i>	<i>Bos taurus</i>	+	Sayin, 1969
<i>auburnensis</i>	<i>Bubalus bubalis</i>	<i>Bos taurus</i>	+	Sayin, 1969
<i>bovis</i>	<i>Bos taurus</i>	<i>Sus scrofa</i>	-	Wilson, 1931
<i>bovis</i>	<i>Bos taurus</i>	<i>Capra hircus</i>	-	Wilson, 1931
<i>bovis</i>	<i>Bubalus bubalis</i>	<i>Bos taurus</i>	+	Sayin, 1969
<i>cylindrica</i>	<i>Bos taurus</i>	<i>Sus scrofa</i>	-	Wilson, 1931
<i>cylindrica</i>	<i>Bos taurus</i>	<i>Capra hircus</i>	-	Wilson, 1931
<i>ovoidalis</i>	<i>Bubalus bubalis</i>	<i>Bos indicus</i>	-	Ray & Mandal, 1961
<i>arlingi</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	±?	Deiana & Delitala, 1953a
		<i>Oryctolagus cuniculus</i>	-	
		<i>Capra cabayae</i>	-	
<i>arlingi</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	-	Krylov, 1961
<i>arlingi</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	-	Tsygankov, Paichuk & Balbaeva, 1963
<i>arlingi</i>	<i>Capra hircus</i>	<i>Saiga tatarica</i>	-	Tsygankov, Paichuk & Balbaeva, 1963
<i>arlingi</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	-	Svanbaev, 1967a
<i>arlingi</i>	<i>Capra sibirica</i>	<i>Ovis aries</i>	-	

TABLE 12 (cont.)

EIMERIA SPECIES	DONOR HOST	RECEPTOR HOST	RESULT	REFERENCE
"arlingtoni"	<i>Capreolus capreolus</i>	<i>Ovis aries</i>	-	
		<i>Saiga tatarica</i>	-	
<i>ninukohllyakimovae</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	-	Svanbaev, 1967a
<i>ninukohllyakimovae</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	+	Subramanian & Jha, 1966
<i>ninukohllyakimovae</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	-	Balozet, 1932a
<i>ninukohllyakimovae</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	-	Lotze et al., 1961
<i>ninukohllyakimovae</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	-	Tsygankov, Patchuk & Balbaeva, 1963
		<i>Saiga tatarica</i>	-	Tsygankov, Patchuk & Balbaeva, 1963
		<i>Ovis aries</i>	-	Svanbaev, 1967a
		<i>Ovis ammon</i>	-	
		<i>Saiga tatarica</i>	-	
		<i>Capreolus capreolus</i>	-	
<i>ninukohllyakimovae</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	-	Krylov, 1961
<i>ninukohllyakimovae</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	-	Lotze et al., 1961
<i>ninukohllyakimovae</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	+	Fitzsimmons, 1964
<i>ninukohllyakimovae</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	-	Tsygankov, Patchuk & Balbaeva, 1963
		<i>Saiga tatarica</i>	-	Tsygankov, Patchuk & Balbaeva, 1963

TABLE 12 (cont.)

EIMERIA SPECIES	DONOR HOST	RECEPTOR HOST	RESULT	REFERENCE
<i>ninakohltyakinovae</i>	<i>Ovis aries</i>	<i>Ovis ammon</i> <i>Capra hircus</i> <i>Capra sibirica</i> <i>Capreolus capreolus</i>	- - - -	Svanbaev, 1967a
<i>ninakohltyakinovae</i>	<i>Ovis ammon</i>	<i>Ovis aries</i> <i>Capra hircus</i> <i>Saiga tatarica</i> <i>Capreolus capreolus</i>	- - - -	Svanbaev, 1967
" <i>ninakohltyakinovae</i> "	<i>Capreolus capreolus</i>	<i>Ovis aries</i> <i>Saiga tatarica</i>	- -	Svanbaev, 1967a
" <i>ninakohltyakinovae</i> "	<i>Saiga tatarica</i>	<i>Ovis aries</i>	-	Svanbaev, 1967a
" <i>ninakohltyakinovae</i> "	<i>Gazella subgutturosa</i>	<i>Ovis aries</i>	-	Svanbaev, 1967a
<i>fauri</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	-	Krylov, 1961
<i>fauri</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	-	Tsygankov, Pačhuk & Balbaeva, 1963
<i>fauri</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	+	Subramanian & Jha, 1966
<i>fauri</i>	<i>Capra hircus</i>	<i>Saiga tatarica</i>	-	Tsygankov, Pačhuk & Balbaeva, 1963
<i>fauri</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	-	Svanbaev, 1967a
<i>fauri</i>	<i>Capra sibirica</i>	<i>Ovis aries</i> <i>Ovis ammon</i> <i>Capreolus capreolus</i> <i>Saiga tatarica</i>	- - - -	Svanbaev, 1967a

TABLE 12 (cont.)

ELMERIA SPECIES	DONOR HOST	RECEPTOR HOST	RESULT	REFERENCE
<i>faurei</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Krylov, 1961
<i>faurei</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Lotze et al., 1961
<i>faurei</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Tsygankov, Palchuk & Balbaeva, 1963
<i>faurei</i>	<i>Ovis aries</i>	<i>Saiga tatarica</i>	—	Tsygankov, Palchuk & Balbaeva, 1963
<i>faurei</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	+	Fitzsimmons, 1964
<i>faurei</i>	<i>Ovis aries</i>	<i>Ovis ammon</i>	—	Svanbaev, 1967a
<i>faurei</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	
		<i>Capra sibirica</i>	—	
		<i>Capreolus capreolus</i>	—	
		<i>Saiga tatarica</i>	—	
		<i>Ovis aries</i>	—	Svanbaev, 1967a
		<i>Capra hircus</i>	—	
		<i>Saiga tatarica</i>	—	
		<i>Capreolus capreolus</i>	—	
		<i>Ovis aries</i>	—	Svanbaev, 1967a
		<i>Ovis aries</i>	—	Svanbaev, 1967a
		<i>Ovis aries</i>	—	Svanbaev, 1967a
		<i>Capra hircus</i>	—	Krylov, 1961
		<i>Capra hircus</i>	—	Lotze et al., 1961
		<i>Capra hircus</i>	—	Tsygankov, Palchuk and Balbaeva, 1963

TABLE 12 (cont.)

<i>EIMERIA</i> SPECIES	DONOR HOST	RECEPTOR HOST	RESULT	REFERENCE
<i>intricata</i>	<i>Ovis aries</i>	<i>Saiga tatarica</i>	—	Tsygankov, Pačhuk and Balbaeva, 1963
<i>intricata</i>	<i>Ovis aries</i>	<i>Ovis ammon</i>	—	Svanbaev, 1967a
		<i>Capra hircus</i>	—	
		<i>Capra sibirica</i>	—	
		<i>Capreolus capreolus</i>	—	
		<i>Saiga tatarica</i>	—	
<i>intricata</i>	<i>Ovis ammon</i>	<i>Ovis aries</i>	—	Svanbaev, 1967a
		<i>Capra hircus</i>	—	
		<i>Saiga tatarica</i>	—	
		<i>Capreolus capreolus</i>	—	
"intricata"	<i>Capreolus capreolus</i>	<i>Ovis aries</i>	—	Svanbaev, 1967a
		<i>Saiga tatarica</i>	—	
"intricata"	<i>Saiga tatarica</i>	<i>Ovis aries</i>	—	Svanbaev, 1967a
"intricata"	<i>Gazella subgutturosa</i>	<i>Ovis aries</i>	—	Svanbaev, 1967a
<i>parva</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	—	Tsygankov, Pačhuk & Balbaeva, 1963
<i>parva</i>	<i>Capra hircus</i>	<i>Saiga tatarica</i>	—	Tsygankov, Pačhuk and Balbaeva, 1963
<i>parva</i>	<i>Capra hircus</i>	<i>Ovis aries</i>	—	Svanbaev, 1967a
<i>parva</i>	<i>Capra sibirica</i>	<i>Ovis aries</i>	—	Svanbaev, 1967a
		<i>Ovis ammon</i>	—	
		<i>Capreolus capreolus</i>	—	
		<i>Saiga tatarica</i>	—	

TABLE 12 (cont.)

EIMERIA SPECIES	DONOR HOST	RECEPTOR HOST	RESULT	REFERENCE
<i>parva</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Krylov, 1961
<i>parva</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Tsygankov, Pačhuk & Balbaeva, 1963
<i>parva</i>	<i>Ovis aries</i>	<i>Saiga tatarica</i>	—	Tsygankov, Pačhuk & Balbaeva, 1963
<i>parva</i>	<i>Ovis aries</i>	<i>Ovis ammon</i>	—	Svanbaev, 1967a
		<i>Capra hircus</i>	—	
		<i>Capra sibirica</i>	—	
		<i>Capreolus capreolus</i>	—	
		<i>Saiga tatarica</i>	—	
<i>parva</i>	<i>Ovis ammon</i>	<i>Ovis aries</i>	—	Svanbaev, 1967a
		<i>Capra hircus</i>	—	
		<i>Capreolus capreolus</i>	—	
		<i>Saiga tatarica</i>	—	
		<i>Capra hircus</i>	—	Fitzsimmons, 1964
“ <i>pallida-parva</i> ”	<i>Ovis aries</i>	<i>Capra hircus</i>	*	Krylov, 1961
<i>granulosa</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Krylov, 1961
<i>crandallii</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Krylov, 1961
<i>absata</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Krylov, 1961
<i>absata</i> (<i>christensei</i> ?)	<i>Capra hircus</i>	<i>Ovis aries</i>	—	Krylov, 1961
<i>ovina</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Krylov, 1961
<i>ovina</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Lotze et al., 1961

TABLE 12 (cont.)

ELMERIA SPECIES	DONOR HOST	RECEPTOR HOST	RESULT	REFERENCE
<i>ovina</i>	<i>Ovis aries</i>	<i>Capra hircus</i>	—	Tsygankov, Pačhuk & Balbaeva, 1963
<i>ovina</i>	<i>Ovis aries</i>	<i>Saiga tatarica</i>	—	Tsygankov, Pačhuk & Balbaeva, 1963
<i>ovina</i>	<i>Ovis aries</i>	<i>Ovis ammon</i>	—	Svanbaev, 1967a
		<i>Capra hircus</i>	—	
		<i>Capra sibirica</i>	—	
		<i>Capreolus capreolus</i>	—	
		<i>Saiga tatarica</i>	—	
<i>ovina</i>	<i>Ovis ammon</i>	<i>Ovis aries</i>	—	Svanbaev, 1967a
		<i>Capra hircus</i>	—	
		<i>Capreolus capreolus</i>	—	
		<i>Saiga tatarica</i>	—	
		<i>Ovis aries</i>	—	
	<i>Gazella subgutturosa</i>	<i>Ovis aries</i>	—	Svanbaev, 1967a
	<i>Saiga tatarica</i>	<i>Ovis aries</i>	—	Svanbaev, 1967a
		<i>Ovis ammon</i>	—	
		<i>Capra sibirica</i>	—	
		<i>Capreolus capreolus</i>	—	
	<i>Taurotragus oryx</i>	<i>Oryctolagus cuniculus</i>	—	Triffitt, 1924

* Could not infect lambs either.

PLATES

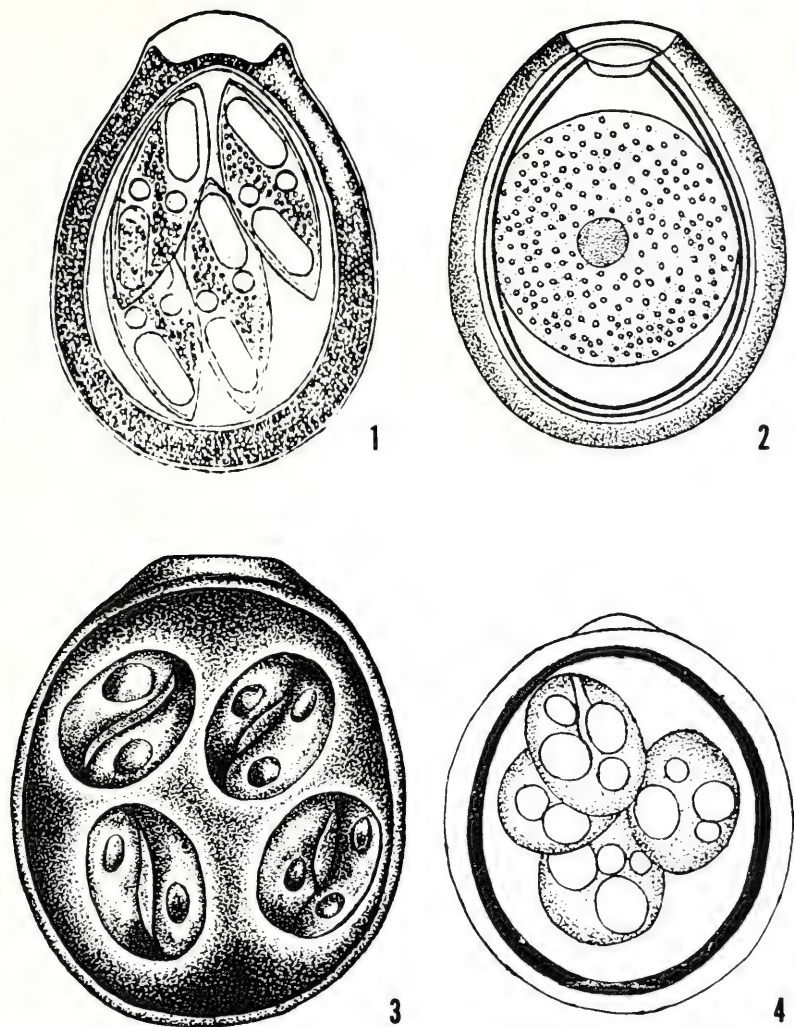


PLATE 1

Fig. 1. *E. cameli* (Henry and Masson, 1932) Reichenow, 1952. Oocyst from the camel (from Tsygankov, 1950 — cited as *E. kazachstanica*). X 700.

Fig. 2. *E. cameli* (Henry and Masson, 1932) Reichenow, 1952. Oocyst from *Camelus dromedarius* (from Dubey and Pande, 1964 — cited as *E. noelleri*). X 1000.

Fig. 3. *E. dromedarii* Yakimoff and Matschoulsky, 1939. Oocyst from *Camelus dromedarius* (from Yakimoff and Matschoulsky, 1939).

Fig. 4. *E. dromedarii* Yakimoff and Matschoulsky, 1939. Oocyst from *Camelus dromedarius* (from Dubey and Pande, 1964). X 2100.

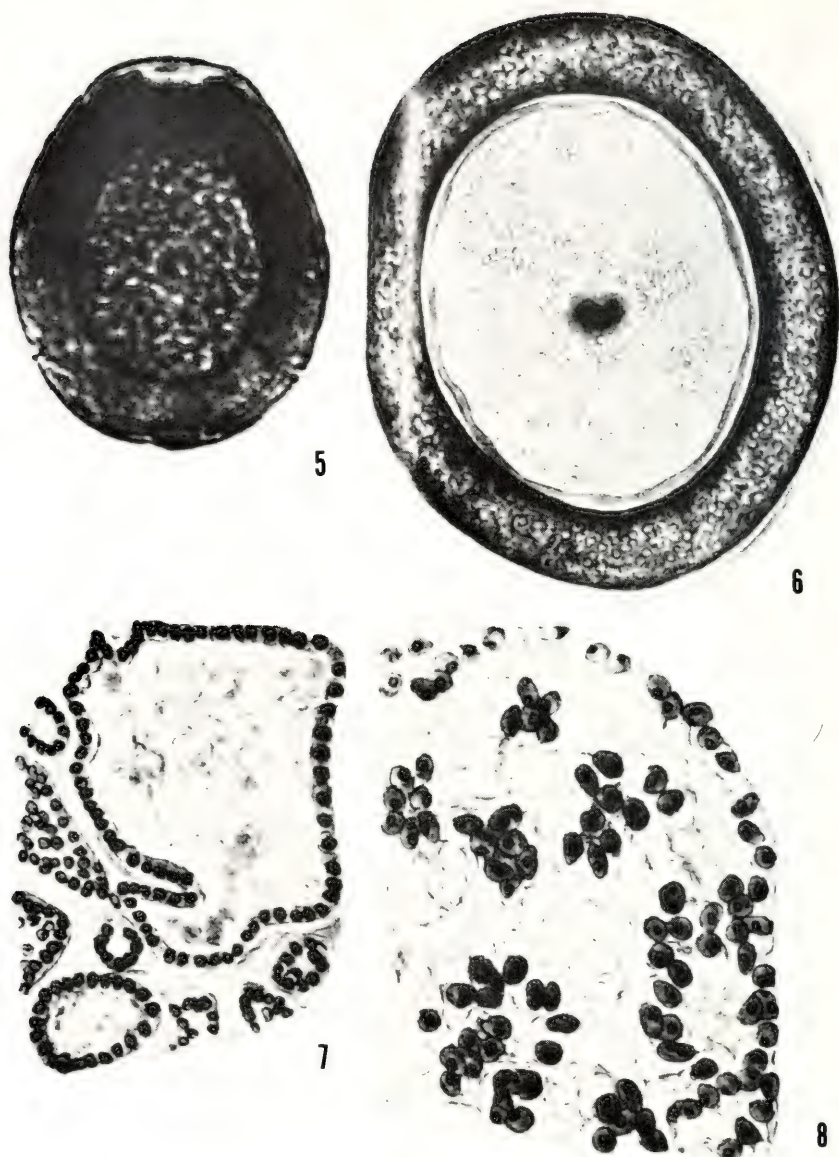
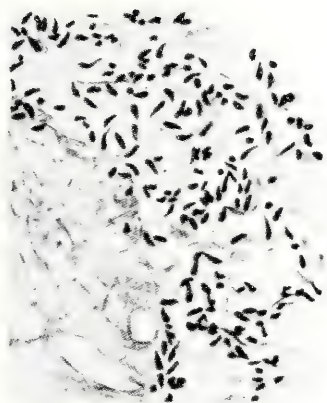


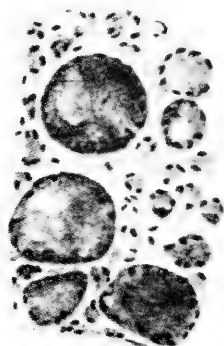
PLATE 2

Fig. 5. *E. cameli* (Henry and Masson, 1932) Reichenow, 1952. Oocyst from *Camelus dromedarius* in the mucosa (from Henry and Masson, 1932b — cited as *Globidium cameli*).

Figs. 6-8. *E. cameli* (Henry and Masson, 1932) Reichenow, 1952, from *Camelus bactrianus* (from Enigk, 1934 — cited as *Globidium cameli*). Fig. 6. Cross section of an unsporulated oocyst. X 1050. Fig. 7. Section of an immature schizont. X 1800. Fig. 8. Section of a schizont or microgametocyte before blastophore formation. X 1900.



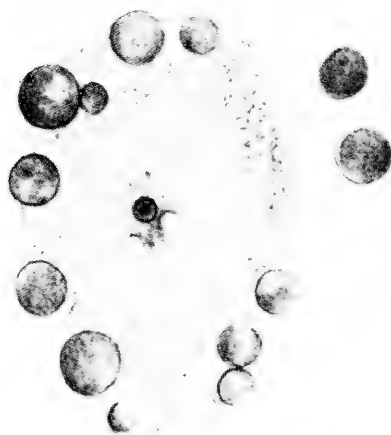
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PLATE 3

Figs. 9-12. *Eimeria cameli* (Henry and Masson, 1932) Reichenow, 1952 from *Camelus bactrianus* (from Enigk, 1934 — cited as *Globidium cameli*). Fig. 9. Section of a ripe schizont. X 1800. Fig. 10. Section of an immature microgametocyte. X 1800. Fig. 11. Section of a mature microgametocyte. X 1800. Fig. 12. Developing macrogamete. X 1200.

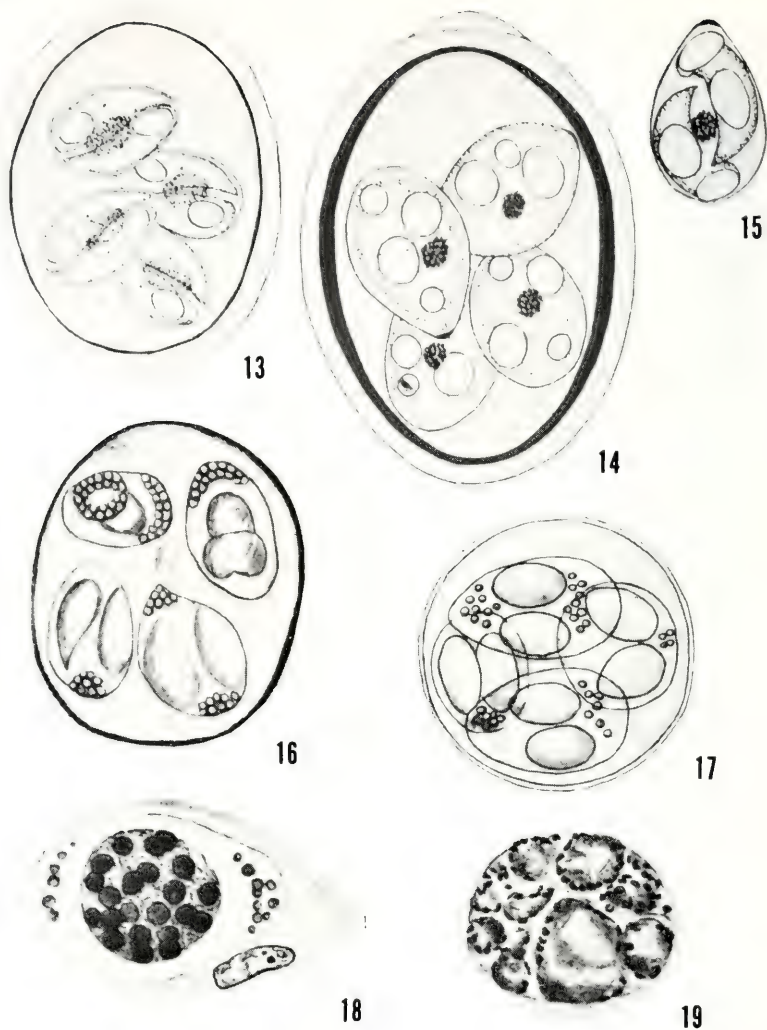


PLATE 4

Fig. 13. *E. pellerdyi* Prasad, 1960 emend. Pellérdy, 1965. Oocyst from *Camelus bactrianus* (from Prasad, 1960). X 2002.

Figs. 14-15. *E. rajasthani* Dubey and Pande, 1963. From *Camelus dromedarius* (from Dubey and Pande, 1963). Fig. 14. Oocyst. X 1638. Fig. 15. Sporocyst. X 1638.

Fig. 16. *E. bactriani* n. sp. Oocyst from the camel (from Iwanoff-Gobzem, 1934 — cited as *E. cameli*).

Fig. 17. *E. bactriani* n. sp. Oocyst from the camel (from Yakimoff, 1935a — cited as *E. cameli*).

Figs. 18-19. *E. bactriani* n. sp. from *Camelus bactrianus* (from Enigk, 1934 — cited as *E. cameli*). Fig. 18. Schizont. X 1638. Fig. 19. Immature microgametocyte. X 1638.

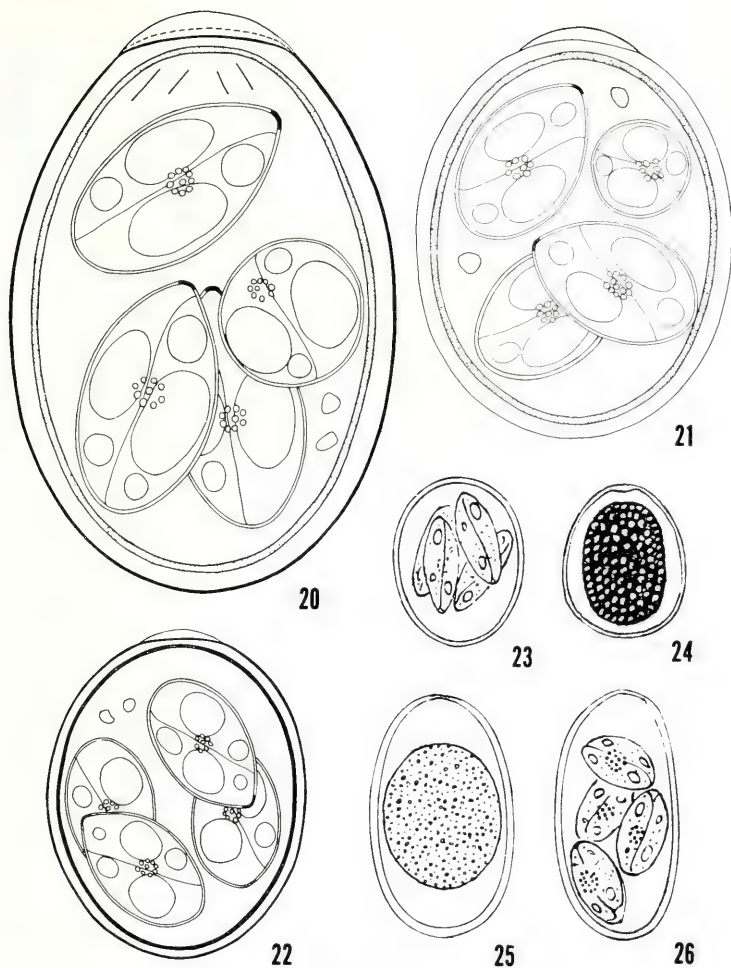


PLATE 5

Fig. 20. *E. lamae* Guerrero, 1967. Oocyst from *Lama pacos* (from Guerrero, 1967). X 2295.

Fig. 21. *E. alpaca* Guerrero, 1967. Oocyst from *Lama pacos* (from Guerrero, 1967). X 2295.

Fig. 22. *E. punoensis* Guerrero, 1967. Oocyst from *Lama pacos* (from Guerrero, 1967). X 2295.

Fig. 23. *E. austriaca* Supperer and Kutzer, 1961. Oocyst from *Cervus elaphus* (from Supperer and Kutzer, 1961). X 1020.

Fig. 24. *E. wassilewskyi* Rastegaieff, 1930. Oocyst from *Axis axis* (from Rastegaieff, 1930).

Figs. 25-26. *E. asymmetrica* Supperer and Kutzer, 1961 from *Cervus elaphus* (from Supperer and Kutzer, 1961). Fig. 25. Unsporulated oocyst. X 1020.

Fig. 26. Sporulated oocyst. X 1020.

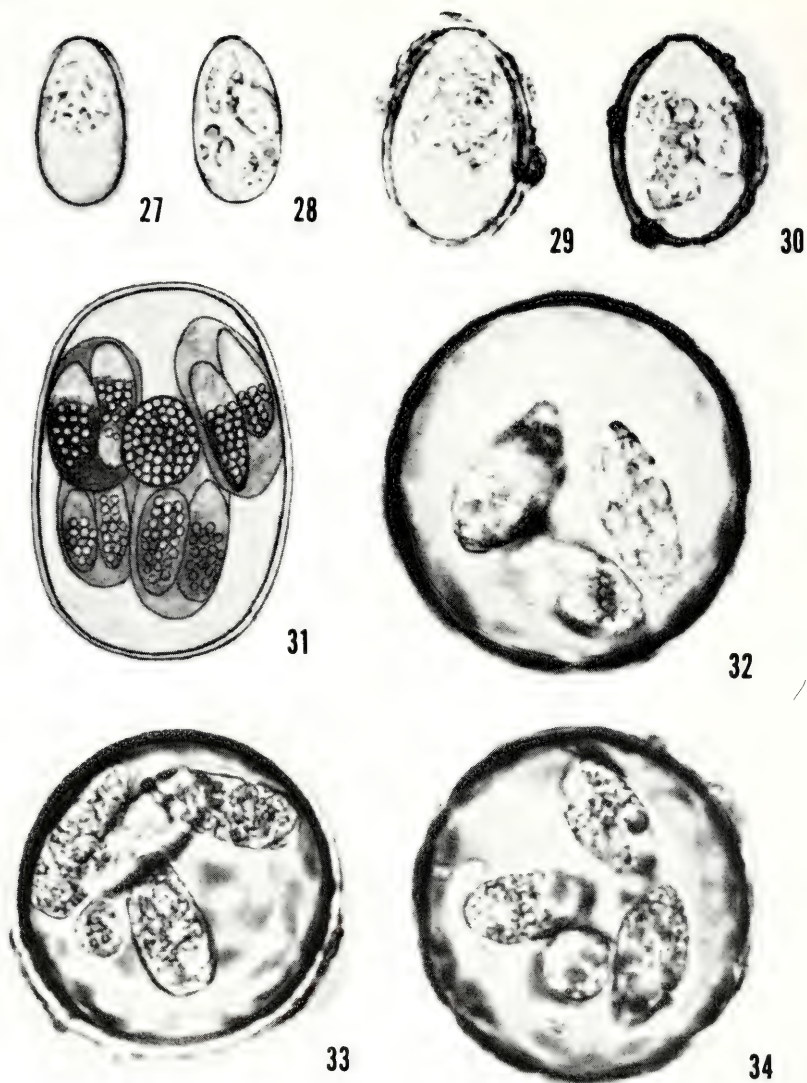


PLATE 6

Figs. 27-28. *E. asymmetrica* Supperer and Kutzer, 1961 from *Cervus elaphus* (from Boch and Lucke, 1961). Fig. 27. Unsporulated oocyst. X 820. Fig. 28. Sporulated oocyst. X 820.

Figs. 29-30. *E. robusta* Supperer and Kutzer, 1961 from *Cervus elaphus* (from Boch and Lucke, 1961 — cited as *E. cervi*). Fig. 29. Unsporulated oocyst. X 820. Fig. 30. Sporulated oocyst. X 820.

Fig. 31. *E. peruviana* Yakimoff, 1934. Oocyst from *Lama glama* (from Yakimoff, 1934).

Figs. 32-34. *E. schoenbuchii* Boch, 1963. Oocysts from *Cervus elaphus* (from Boch, 1963). X 820.

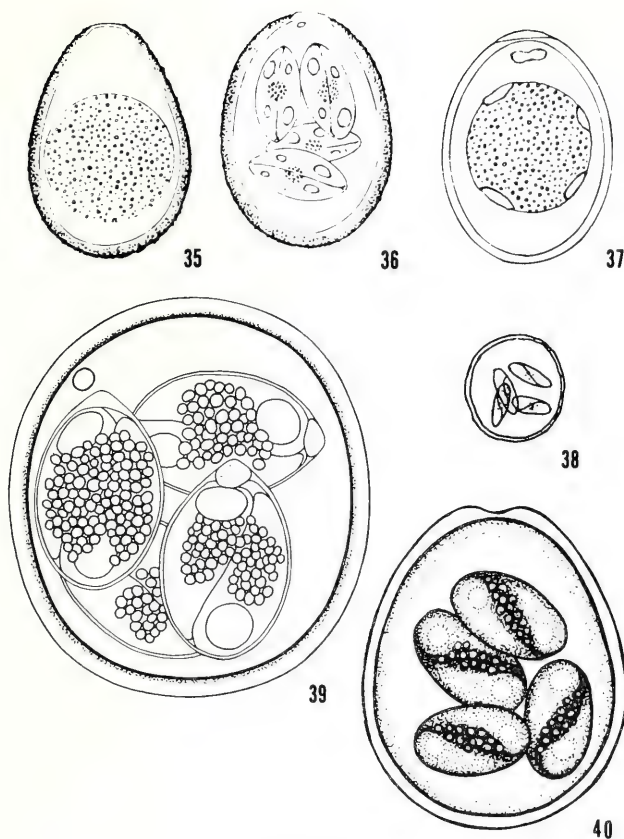


PLATE 7

Figs. 35-36. *E. robusta* Supperer and Kutzer, 1961 from *Cervus elaphus* (from Supperer and Kutzer, 1961). Fig. 35. Unsporulated oocyst. X 740. Fig. 36. Sporulated oocyst. X 740.

Fig. 37. *E. sordida* Supperer and Kutzer, 1961 from *Cervus elaphus* (from Supperer and Kutzer, 1961). X 962.

Fig. 38. *E. elaphi* Jansen and van Haaften, 1966 from *Cervus elaphus* (from Jansen and van Haaften, 1966).

Fig. 39. *E. odocoilei* Levine, Ivins and Senger, 1967 from *Odocoileus h. hemionus* (from Levine, Ivins and Senger, 1967). X 1924.

Fig. 40. *E. arctica* Yakimoff, Matschoulsky and Spartansky, 1939 from *Rangifer tarandus* (from Yakimoff, Matschoulsky and Spartansky, 1939).

PLATE 8

Fig. 41. *E. wapiti* Honess, 1955 from *Cervus canadensis nelsoni* (from Honess, 1955).

Fig. 42. *E. mayeri* Yakimoff, Sokoloff and Matschoulsky, 1936 from *Rangifer tarandus* (from Yakimoff, Sokoloff and Matschoulsky, 1936).

Fig. 43. *E. muchlensi* Yakimoff, Sokoloff and Matschoulsky, 1936 from *Rangifer tarandus* (from Yakimoff, Sokoloff and Matschoulsky, 1936).

Fig. 44. *E. tarandina* Yakimoff, Sokoloff and Matschoulsky, 1936 from *Rangifer tarandus* (from Yakimoff, Sokoloff and Matschoulsky, 1936).

Figs. 45-46. *E. ponderosa* Wetzel, 1942 from *Capreolus capreolus* (from Boch and Lucke, 1961). Fig. 45. Sporulated oocyst. X 850. Fig. 46. Sporulated oocyst. X 820.

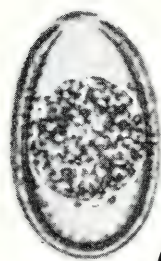
Fig. 47. *E. panda* Supperer and Kutzer, 1961 from *Capreolus capreolus* (from Boch and Lucke, 1961). X 650.

Fig. 48. *E. ponderosa* Wetzel, 1942 from *Capreolus capreolus* (from Wetzel, 1942). X 1000.

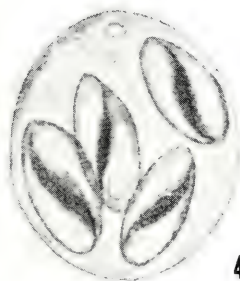
Fig. 49. *E. superba* Pellérdy, 1955 from *Capreolus capreolus* (from Boch and Lucke, 1961). X 850.

Fig. 50. *E. sp.* Boch and Lucke, 1961 from *Capreolus capreolus* (from Boch and Lucke, 1961). X 850.

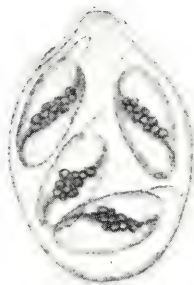
Fig. 51. *E. rotunda* Pellérdy, 1955 from *Capreolus capreolus* (from Boch and Lucke, 1961). X 820.



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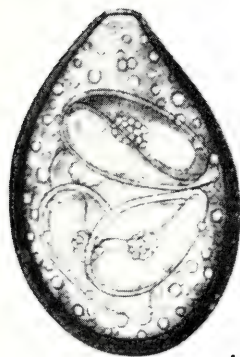
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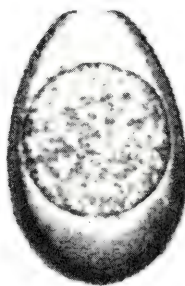
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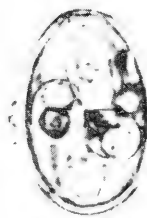
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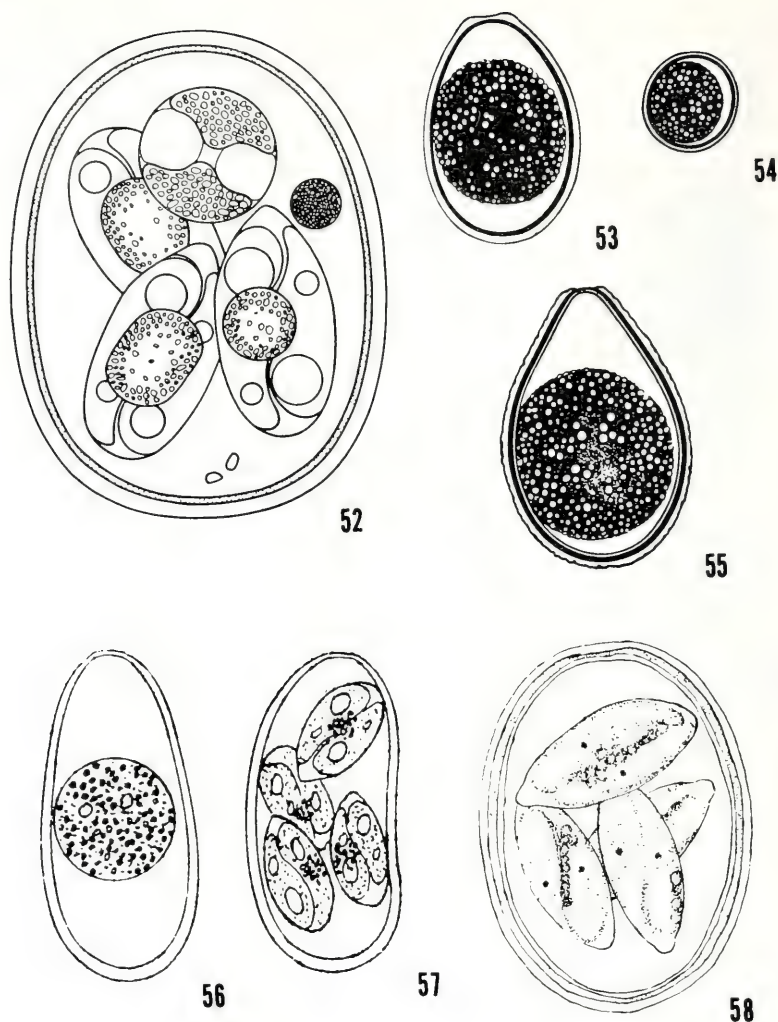


PLATE 9

Fig. 52. *E. antilocaprae* Huizinga, 1942 from *Antilocapra americana* (from Todd, Hammond, and O'Gara, 1967). X 2057.

Fig. 53. *E. capreoli* Galli-Valerio, 1927 from *Capreolus capreolus* (from Pellérdy, 1955).

Fig. 54. *E. rotunda* Pellérdy, 1955 from *Capreolus capreolus* (from Pellérdy, 1955).

Fig. 55. *E. ponderosa* Wetzel, 1942 from *Capreolus capreolus* (from Pellérdy, 1955).

Figs. 56-57. *E. panda* Supperer and Kutzer, 1961 from *Capreolus capreolus* (from Supperer and Kutzer, 1961). X 1169. Fig. 56. Unsporulated oocyst. Fig. 57. Sporulated oocyst.

Fig. 58. *E. canna* Triffitt, 1924 from *Taurotragus oryx* (from Triffitt, 1924).

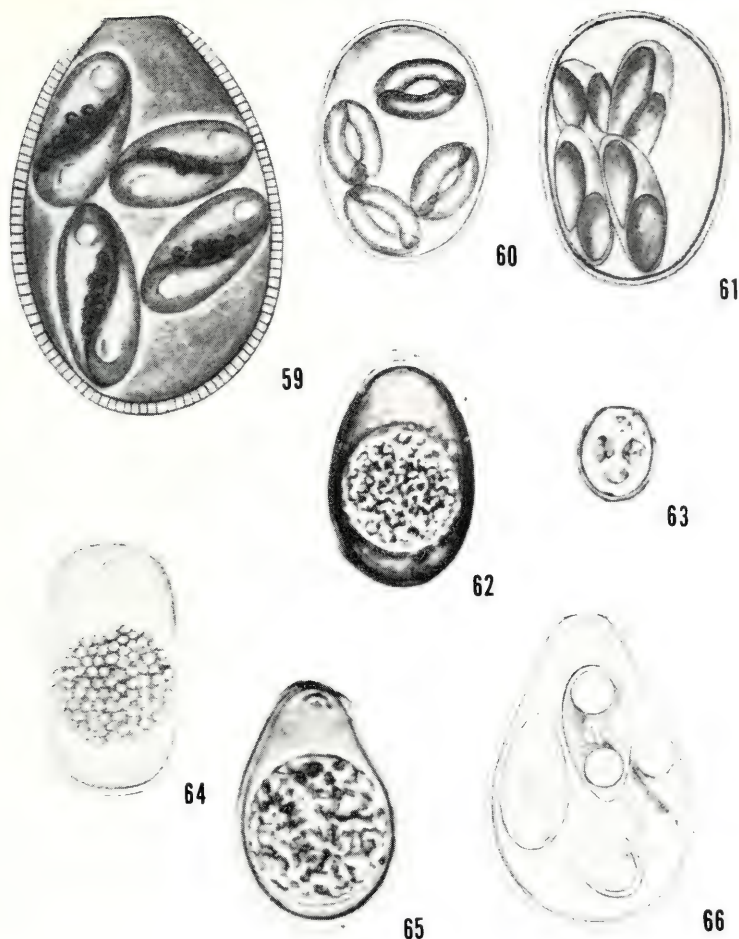


PLATE 10

Fig. 59. *E. macieli* Yakimoff and Matchulski, 1938 from *Kobus ellipsiprymnus* (from Yakimoff and Matchulski, 1938).

Fig. 60. *E. arkhari* Yakimoff and Matschoulsky, 1937 from *Ovis vignei* (from Yakimoff and Matschoulsky, 1937a).

Fig. 61. *E. trifittae* Yakimoff, 1934 emend. from *Taurotragus oryx* (from Yakimoff, 1934).

Fig. 62. *E. mccordocki* Honess, 1941 from *Odocoileus h. hemionus* (from Landram and Honess, 1955).

Fig. 63. *E. austriaca* Supperer and Kutzer, 1961 from *Cervus elaphus* (from Boch and Lucke, 1961). X 735.

Fig. 64. *E. (?) polaris* Yakimoff and Sokoloff, 1935 from *Rangifer tarandus* (from Yakimoff, Sokoloff and Matschoulsky, 1936).

Figs. 65-66. *E. bareillyi* Gill, Chhabra and Lall, 1963 from *Bubalus bubalis* (from Gill, Chhabra and Lall, 1963). Fig. 65. Unsporulated oocyst. Fig. 66. Sporulated oocyst. X 1211.

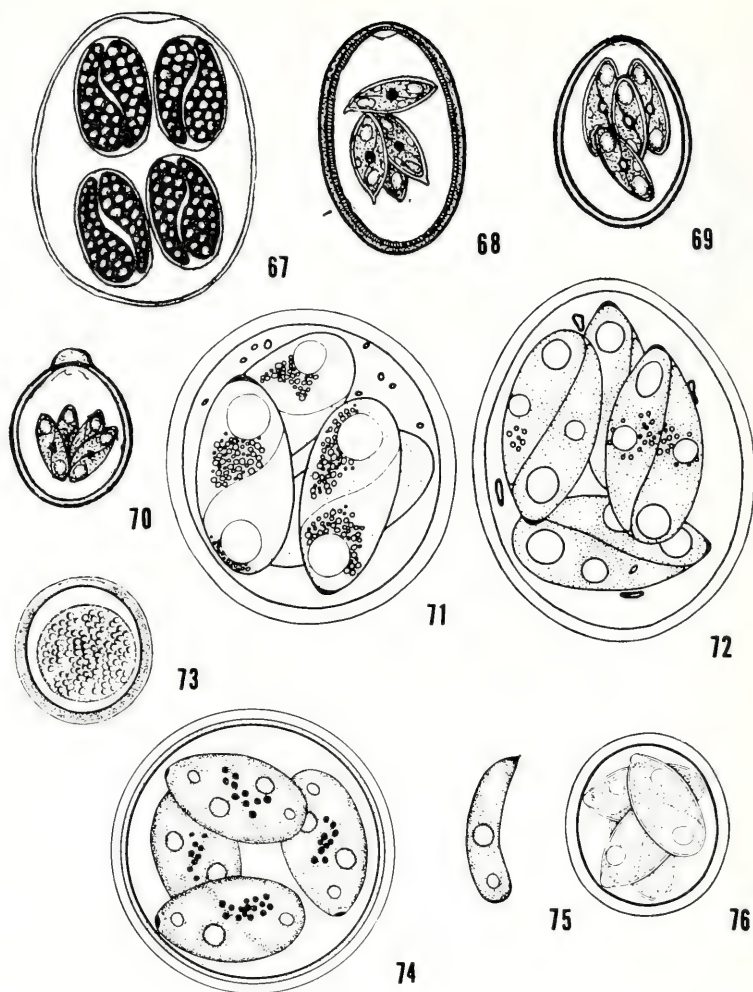


PLATE 11

Fig. 67. *E. yakimovi* Rastegaieff, 1929 from *Boselaphus tragocamelus* (from Rastegaieff, 1930).

Fig. 68. *E. thianethi* Gwéléssiany, 1935 from *Bubalus bubalis* (from Patnaik, 1965). X 770.

Fig. 69. *E. ovoidalis* Ray and Mandal, 1961 from *Bubalus bubalis* (from Patnaik, 1965 — cited as *E. wyomingensis*). X 770.

Fig. 70. *E. gokaki* Rao and Bhatavdekar, 1959 from *Bubalus bubalis* (from Patnaik, 1965 — cited as *E. brasiliensis*). X 770.

Figs. 71-76. *E. zuernii* (Rivolta, 1878) Martin, 1909 from *Bos taurus*. Fig. 71. Oocyst (from Levine and Ivens, 1967). X 2308. Fig. 72. Same as Fig. 71. Fig. 73. Oocyst (from Christensen, 1941). X 1154. Fig. 74. Oocyst (from Nyberg and Hammond, 1965). X 2138. Fig. 75. Sporozoite (from Nyberg and Hammond, 1965). X 2138. Fig. 76. Oocyst (from Joyner et al., 1966). X 1389.

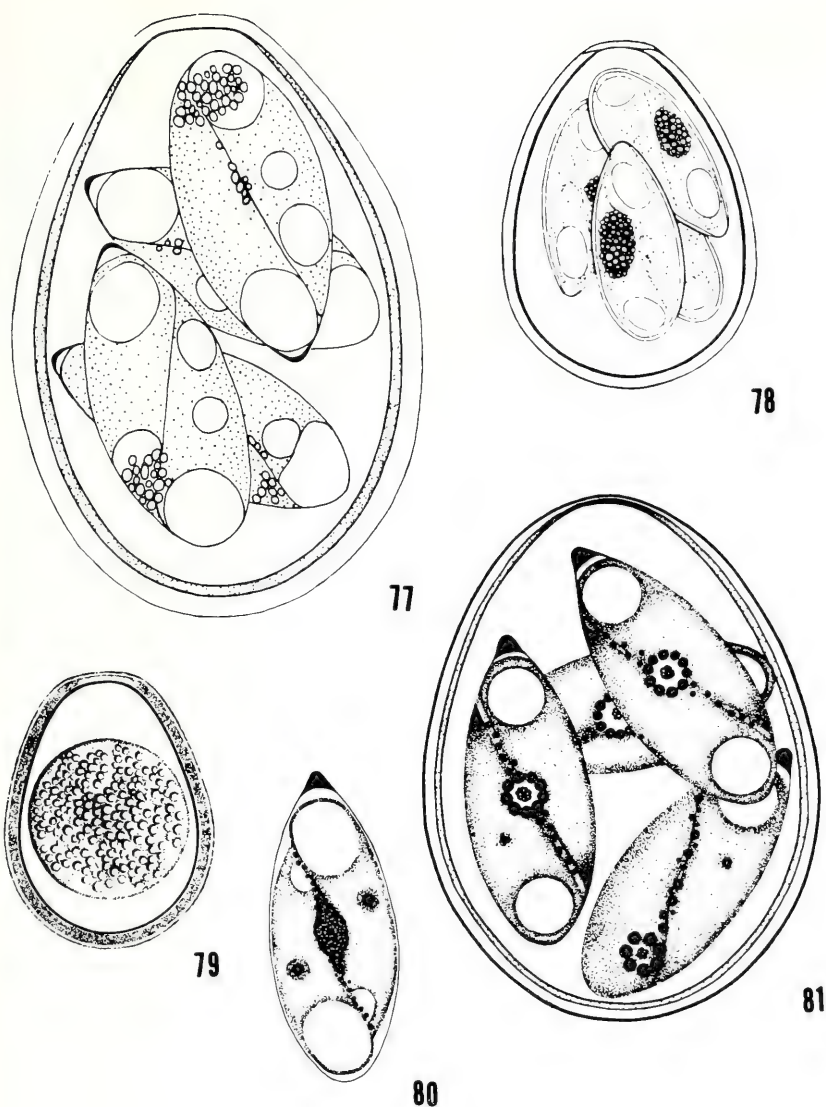


PLATE 12

Figs. 77-81. *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus*. Fig. 77. Oocyst (from Levine and Ivens, 1967). X 2700. Fig. 78. Oocyst (from Joyner et al., 1966). X 1625. Fig. 79. Oocyst (from Christensen, 1941). X 1350. Fig. 80. Sporocyst (from Nyberg and Hammond, 1965). X 2500. Fig. 81. Oocyst (from Nyberg and Hammond, 1965). X 2500.

PLATE 13

Figs. 82-92. *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Hammond, Ernst and Goldman, 1965). Fig. 82. Fresh schizonts concentrated in a petri dish. X 1,24. Fig. 83. Fresh schizonts. X 14. Fig. 84. Fresh merozoite. Phase contrast. X 1432. Fig. 85. Fresh merozoite undergoing flexion. Wrinkles in bent region (arrow). Phase contrast. X 1432. Fig. 86. Merozoite, protargol preparation, showing nucleus (arrow) and cytoplasmic granules. X 1910. Fig. 87. Merozoites, protargol preparation, showing anterior cap (upper arrow) and cytoplasmic granules including posterior granule (lower arrow). X 1910. Fig. 88. Merozoite, protargol preparation, showing anterior cap (top), cytoplasmic granules (center), nucleus (near bottom), and posterior granule (arrow). Dark field. X 1910. Fig. 89. Merozoite, protargol preparation, with continuous membrane over anterior end (arrow). Dark field. X 1910. Fig. 90. Merozoite, protargol preparation showing longitudinal fibrils. X 1910. Fig. 91. Merozoites, protargol preparation. One showing pore at anterior end (arrow). X 1910. Fig. 92. Merozoite, protargol preparation, showing median rodlike structure in anterior portion of body (arrow). X 1910.

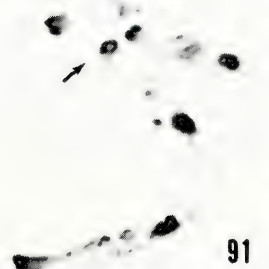
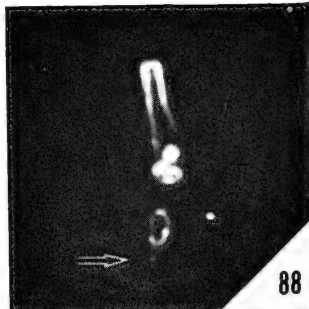
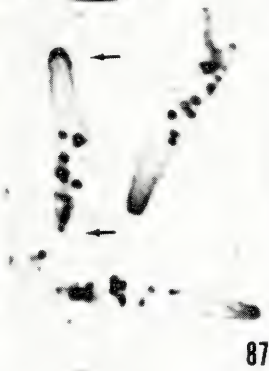
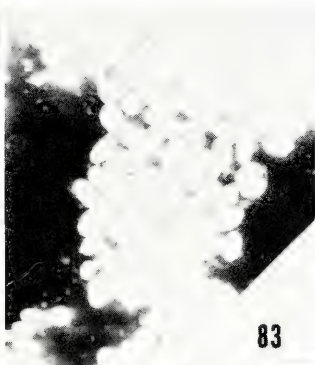




PLATE 14

Figs. 93-96. *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Hammond, 1964). Fig. 93. Section of villus with 2 nearly mature 1st generation schizonts, one showing the host cell nucleus (arrow); fixed in Zenker's and stained with iron-hematoxylin. X 143. Fig. 94. Early 2nd generation schizont fixed in Helly's and stained with iron-hematoxylin. X 1337. Fig. 95. Intermediate 2nd generation schizont fixed in Helly's and stained with iron-hematoxylin. X 1337. Fig. 96. Mature 1st generation schizont; fresh specimen. X 191.

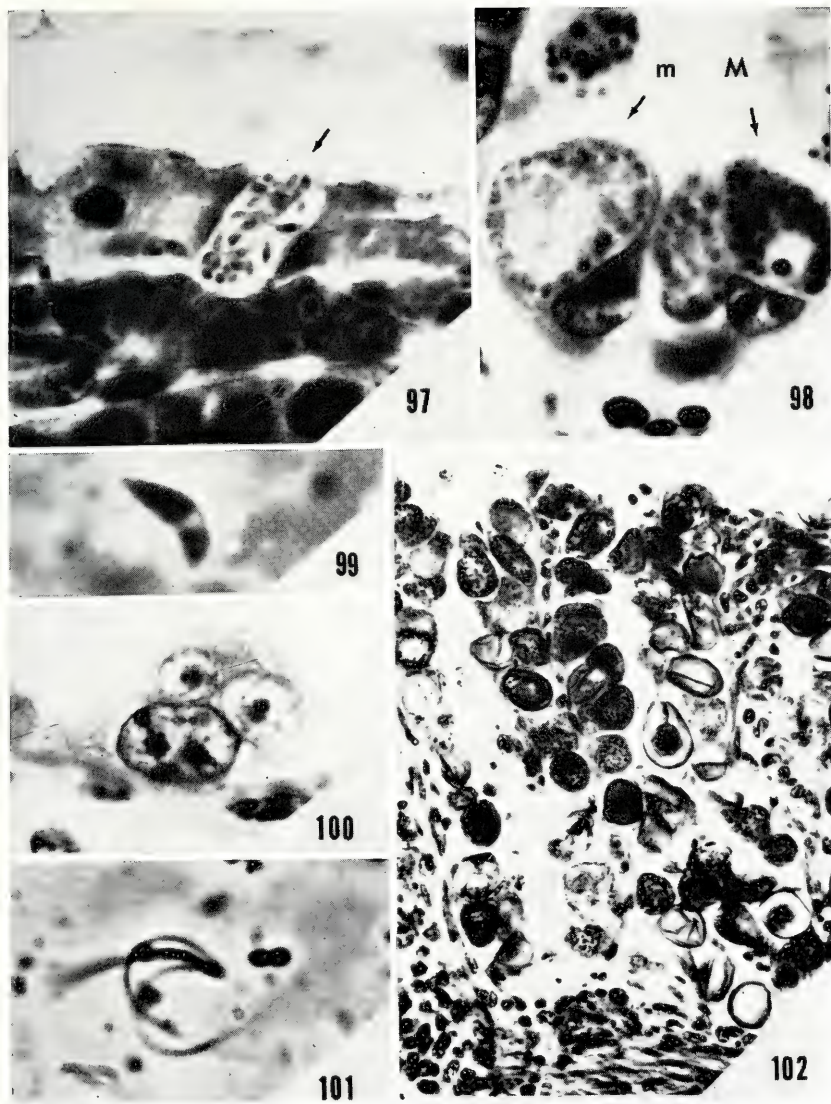


PLATE 15

Figs. 97-102. *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Hammond, 1964). Fig. 97. Mature 2nd generation schizont containing merozoites. X 1337. Fig. 98. Intermediate gamonts; microgametocyte (m) and macrogamete (M). X 1337. Fig. 99. Second generation merozoite, fresh specimen. X 2388. Fig. 100. Two early gamonts in the same host cell. X 1337. Fig. 101. Microgamete, fresh specimen, phase contrast. X 2865. Fig. 102. Oocysts and maturing gamonts with severe damage to the mucosa. X 287.

(Figs. 97, 98, 100 and 102 from preparations fixed in Helly's and stained with iron-hematoxylin.)

PLATE 16

Figs. 103-106. *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus*. Fig. 103. Unsporulated oocyst (from Hammond, 1964). X 1067. Fig. 104. Sporulated oocyst (from Hammond, 1964). X 1067. Fig. 105. Excysting oocyst with a sporozoite escaping and other sporozoites still inside (from Hammond, 1964). X 1455. Fig. 106. Electron micrograph of section showing numerous randomly oriented merozoites in host cell vacuole (from Sheffield and Hammond, 1966). X 6305.



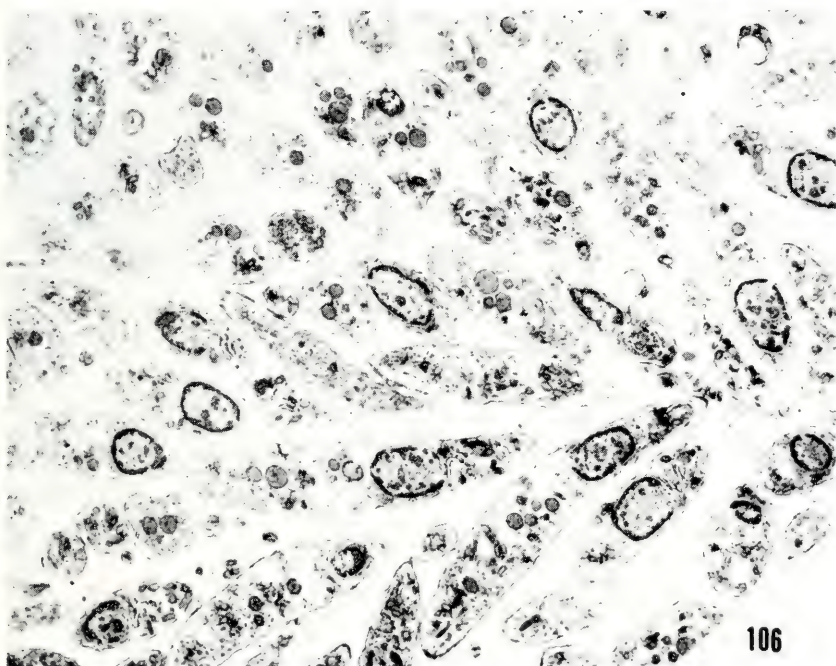
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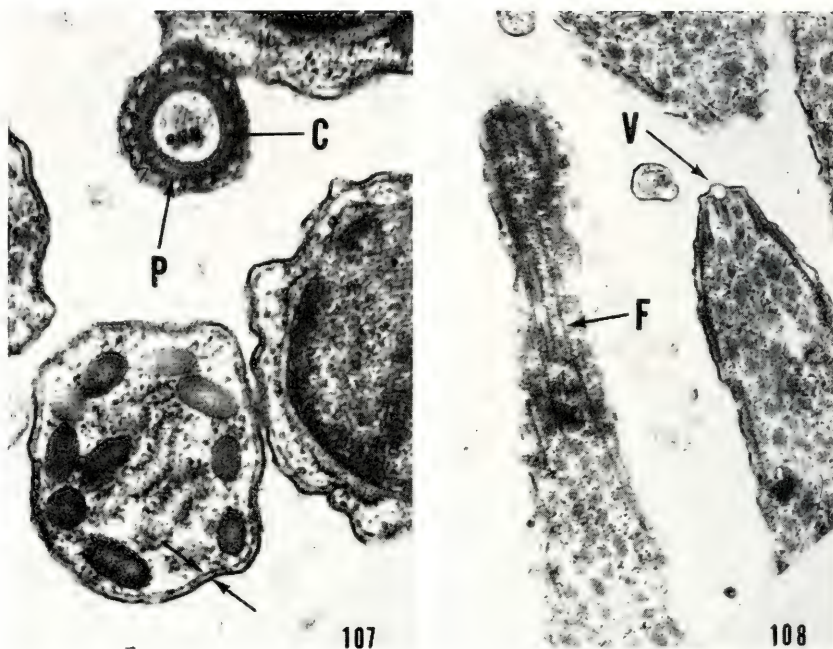


PLATE 17

Figs. 107-108. Electron micrographs of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Sheffield and Hammond, 1966). Fig. 107. Cross section of several merozoites. Note rhoptries (paired organelle) and median rod within the conoid, fibrils apparently attached to polar ring and the 2 membranes (arrows) surrounding the cell. X 40,320. Fig. 108. Longitudinal section of 2 merozoites showing subpellicular fibrils in one and anterior vesicle in the other. X 23,184.

C, conoid; F, fibril; P, polar ring; V, vesicle.

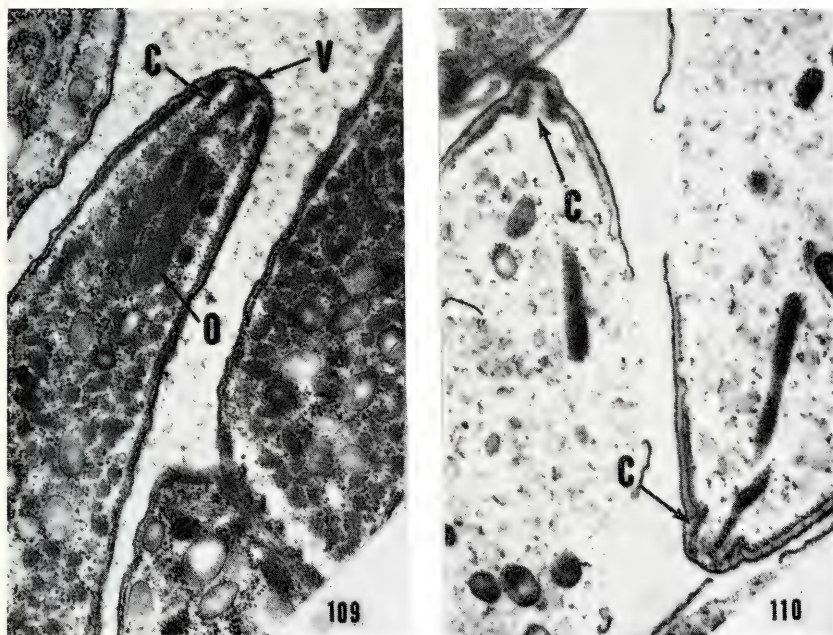


PLATE 18

Figs. 109-110. Electron micrographs of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Sheffield and Hammond, 1966). Fig. 109. Anterior end of a merozoite with a vesicle at the end of the rhoptries (paired organelle). X 24,450. Fig. 110. Section of 2 conoids. Note the small circular profiles in the lower conoid and the parallel striations in the upper conoid. X 24,450.

C, conoid; O, rhoptries; V, vesicle.

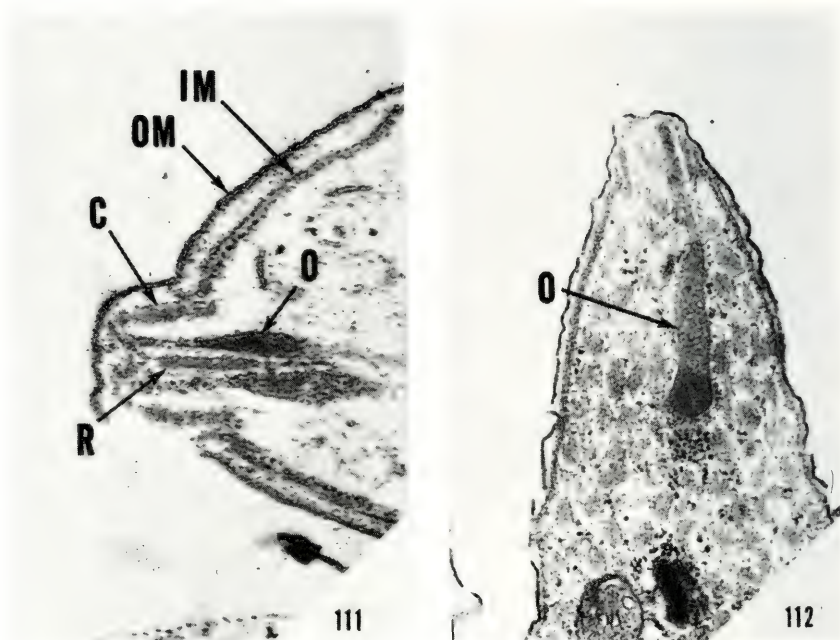


PLATE 19

Figs. 111-112. Electron micrographs of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Sheffield and Hammond, 1966). Fig. 111. Longitudinal section of the anterior end of a merozoite showing the median rod between the necks of the rhoptries (paired organelle). X 72,600. Fig. 112. Section through one member of the rhoptries. Note alveolar and dense portions of the club-shaped part of the rhoptries. X 34,650.

C, conoid; IM, inner membrane; O, rhoptries; OM, outer membrane; R, median rod.



113

PLATE 20

Fig. 113. Electron micrograph of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Sheffield and Hammond, 1966). Longitudinal section of several merozoites showing the position of the cell components near the nucleus. X 25,950.

ER, endoplasmic reticulum; G, Golgi zone; GL, glycogen body; L, lysosome; M, mitochondrion; N, nucleus.



PLATE 21

Fig. 114. Electron micrograph of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Sheffield and Hammond, 1966). Anterior end of 2 merozoites in which the tortuous structures (arrow) are well defined. The host cell is visible in the lower portion of the micrograph. X 23,335.

M, mitochondrion; O, rhoptries (paired organelles).

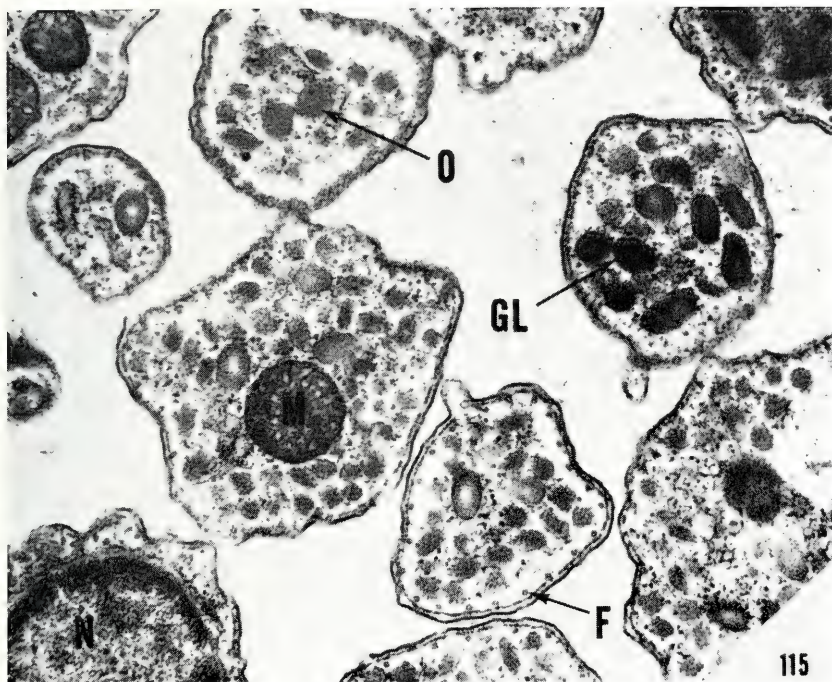


PLATE 22

Fig. 115. Electron micrograph of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Sheffield and Hammond, 1966). Cross section of several merozoites cut at different levels. Note the 22 fibrils just internal to the inner membrane and tortuous structures. X 34,600.

F, fibril; GL, glycogen body; M, mitochondrion; N, nucleus; O, rhoptries (paired organelle).

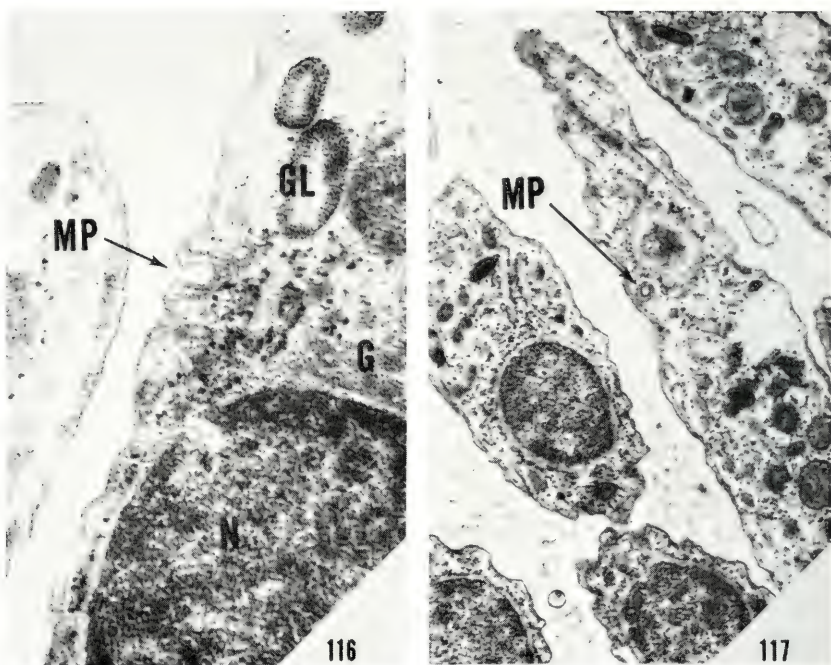


PLATE 23

Figs. 116-117. Electron micrographs of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Sheffield and Hammond, 1966). Fig. 116. Section through the lateral invagination of a merozoite. X 54,400. Fig. 117. Merozoite cut just below the surface showing a cross section of the invagination. X 18,870.

G, Golgi zone; GL, glycogen body; MP, invagination; N, nucleus.

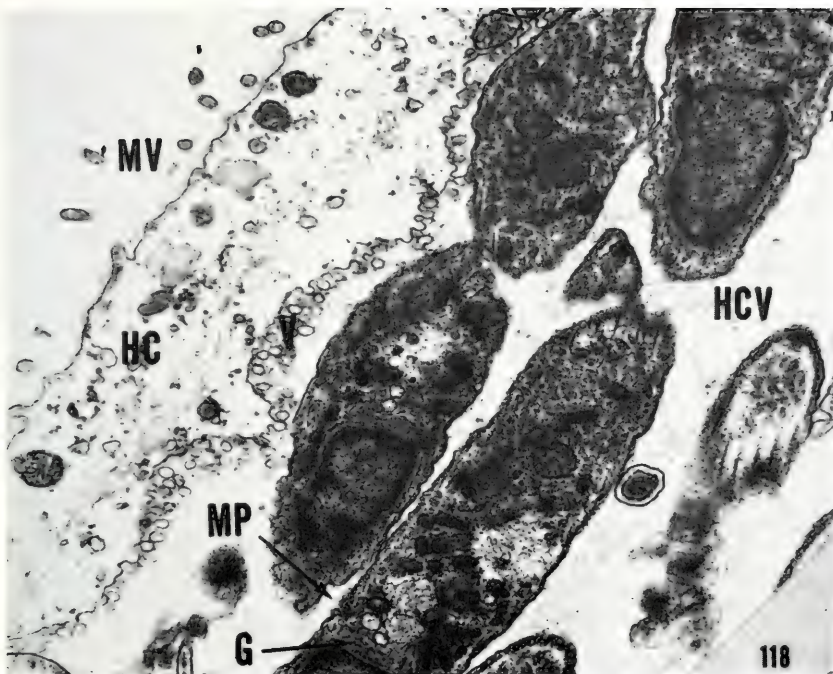


PLATE 24

Fig. 118. Electron micrograph of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Sheffield and Hammond, 1966). Section through a portion of the host cell containing merozoites. Note the microvilli on the outer surface of the blebs and vesicles along the limiting membrane of the host cell vacuole. Two irregularly shaped lipid inclusions are present in the host cell. X 17,992. G, Golgi zone; HC, host cell; HCV, host cell vacuole; MP, invagination; MV, microvilli; V, vesicle.



PLATE 25

Fig. 119. Electron micrograph of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Scholtyssek, Hammond and Ernst, 1966). Macrogamete within host cell. X 14,790.

DB, dark bodies; G, glycogen granules; H, host cell; L, lipoid inclusions; ME, cell membrane of parasite; MI, micropore; WB, wall-forming bodies.

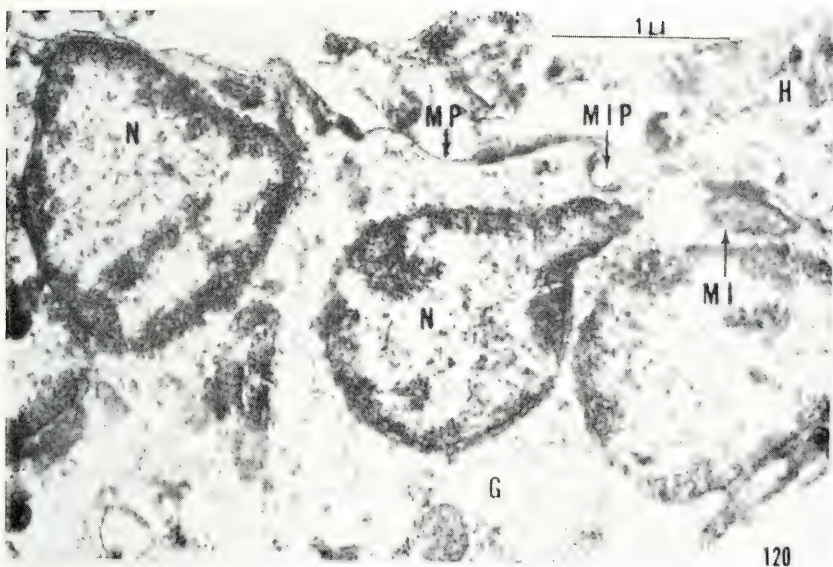


PLATE 26

Fig. 120. Electron micrograph of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Hammond, Scholtyseck and Miner, 1967). Peripheral portion of microgametocyte showing micropore. X 23,400.

G, glycogen granule; H, host cell; N, nucleus; MI, mitochondrion; MIP, micropore; MP, cell membrane of parasite.

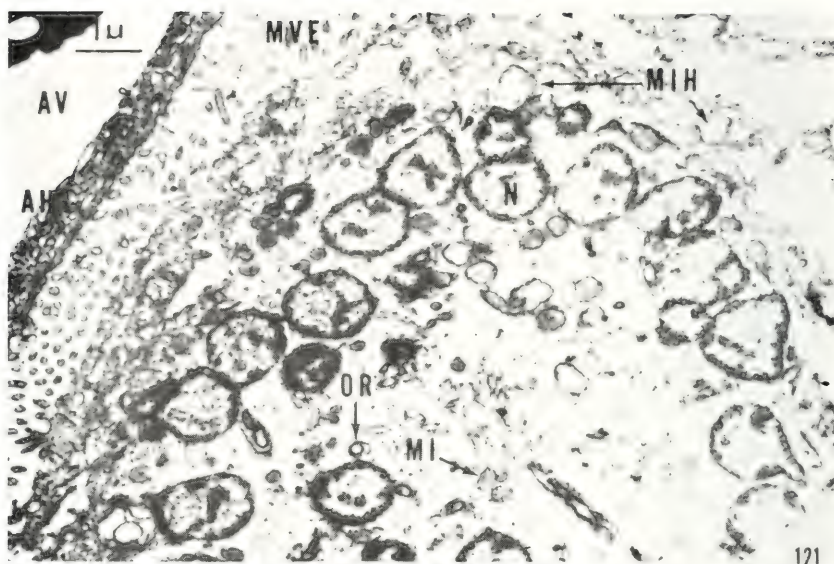


PLATE 27

Fig. 121. Electron micrograph of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Hammond, Scholtyseck and Miner, 1967). Microgametocyte; stage with nuclei completing division. X 8580.

AH, adjacent host cell harboring macrogamete within vacuole (AV); MI, mitochondrion; MIH, mitochondria of the host cell; MVE, external microvilli of the host cell; OR, osmiophilic ring adjacent to nuclear membrane.

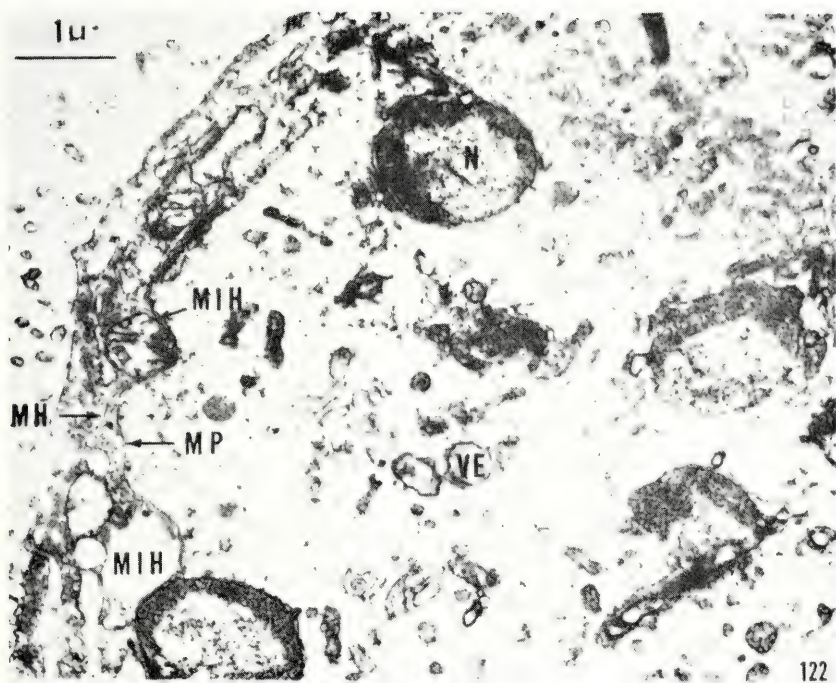


PLATE 28

Fig. 122. Electron micrograph of *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus* (from Hammond, Scholtyssek and Miner, 1967). Microgametocyte; older stage showing a close spatial relationship between parasite and host cell. X 12,400.

MH, cytoplasmic membranes of the host cell; MIH, mitochondrion of the host cell; MP, cell membrane of the parasite; N, nucleus; VE, different kinds of vesicles.

PLATE 29

Figs. 123-126. *E. bovis* (Züblin, 1908) Fiebiger, 1912 from *Bos taurus*. Fig. 123. Sporozoite showing location of glycogen granules. Based on PAS preparations (from Hammond, Chobotar and Ernst, 1968). X 3800. Fig. 124. Sporozoite, typical form, drawn from fresh specimens (from Hammond, Chobotar and Ernst, 1968). X 3800. Fig. 125. Nucleus of 1st generation merozoite as seen in Feulgen preparation (from Hammond, Ernst and Goldman, 1965). X 8000. Fig. 126. First generation merozoite showing distribution of glycogen granules as seen in PAS preparation (from Hammond, Ernst and Goldman, 1965). X 4000.

Fig. 127. Diagram of the ultrastructure of a young macrogamete of the genus *Eimeria* (from Scholtyseck, Hammond and Ernst, 1966).

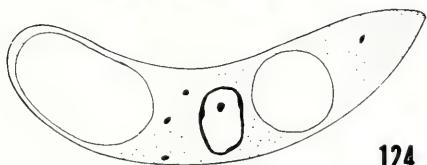
DB, dark bodies; ER, endoplasmic reticulum; G, glycogen granules; L, lipid inclusions; M, mitochondria; N, nucleus; NU, nucleolus; OM, osmiophilic masses; P, pores in nuclear membrane; TL, longitudinal sections of microtubules; TT, transverse sections of microtubules; V, small vesicles of the endoplasmic reticulum; VER, large vesicles of the endoplasmic reticulum; WB, wall-forming bodies.

Fig. 128. Diagram of the ultrastructure of a young microgametocyte of the genus *Eimeria* (from Hammond, Scholtyseck and Miner, 1967).

ER, endoplasmic reticulum; G, glycogen granule; L, lipid inclusion; MI, mitochondrion; N, nucleus; NU, nucleolar substance; P, pore in nuclear membrane; VE, different kinds of vesicles.



123



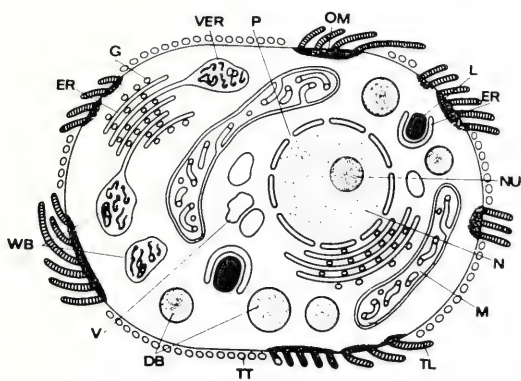
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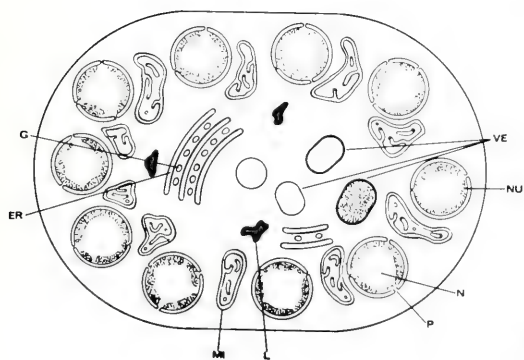
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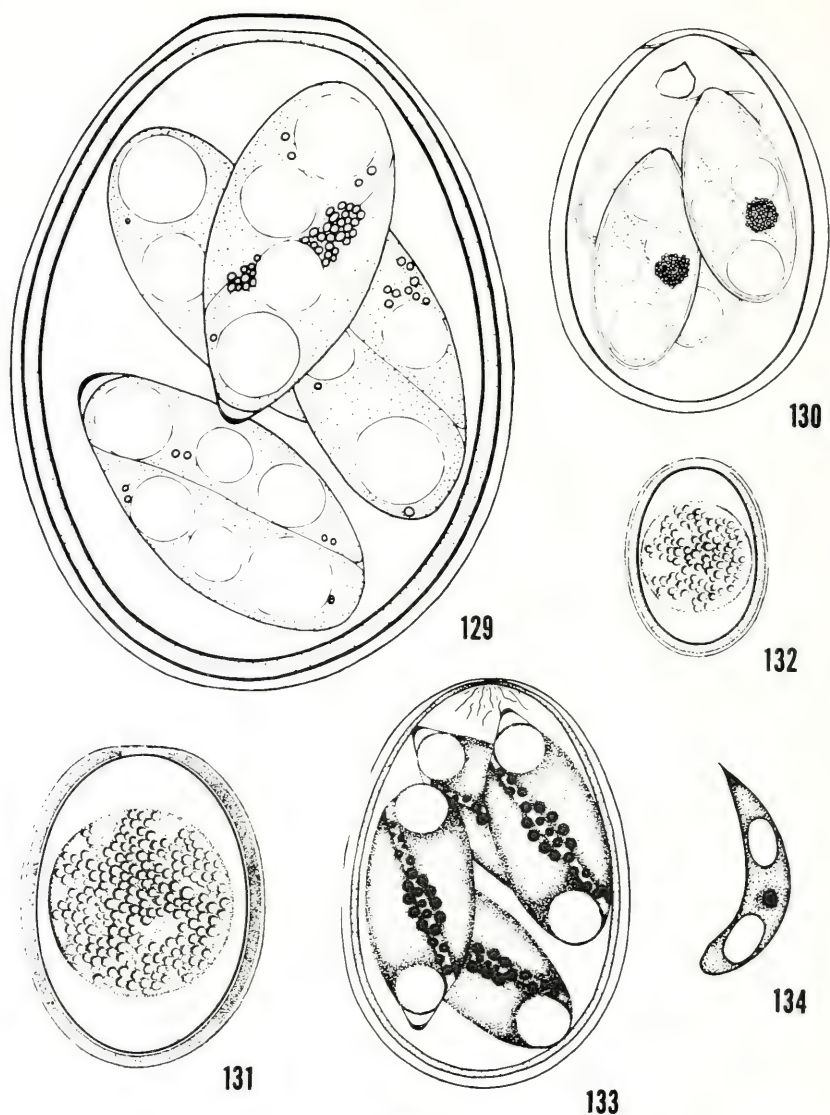


PLATE 30

Figs. 129-131. *E. canadensis* Bruce, 1921 from *Bos taurus*. Fig. 129. Oocyst (from Levine and Ivens, 1967). X 2592. Fig. 130. Oocyst (from Joyner et al., 1966). X 1560. Fig. 131. Oocyst (from Christensen, 1941). X 1296.

Figs. 132-134. *E. ellipsoidalis* Becker and Frye, 1929 from *Bos taurus*. Fig. 132. Oocyst (from Christensen, 1941). X 1296. Fig. 133. Oocyst (from Nyberg and Hammond, 1965). X 2400. Fig. 134. Sporocyst (from Nyberg and Hammond, 1965). X 2400.

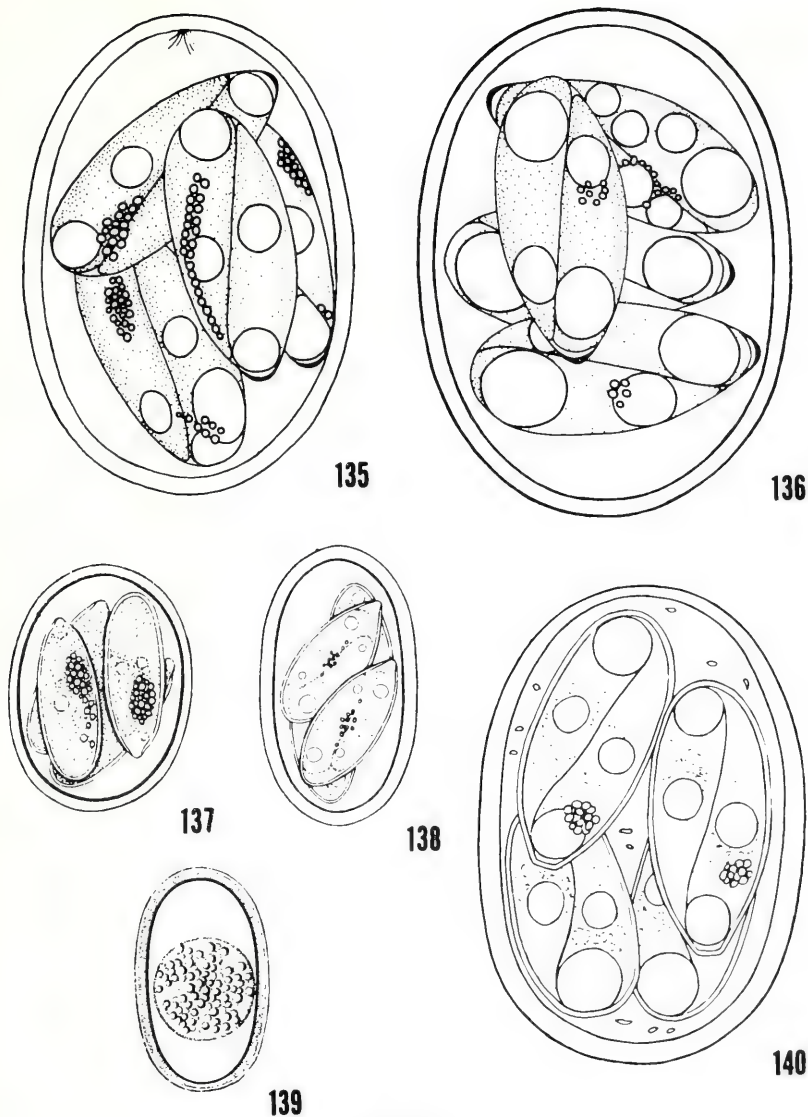


PLATE 31

Figs. 135-137. *E. ellipsoidalis* Becker and Frye, 1929 from *Bos taurus*. Figs. 135 and 136. Oocysts (from Levine and Ivens, 1967). X 2700. Fig. 137. Oocyst (from Joyner et al., 1966). X 1625.

Figs. 138-140. *E. cylindrica* Wilson, 1931 from *Bos taurus*. Fig. 138. Oocyst (from Joyner et al., 1966). X 1625. Fig. 139. Oocyst (from Christensen, 1941). X 1350. Fig. 140. Oocyst (from Levine and Ivens, 1967). X 2700.

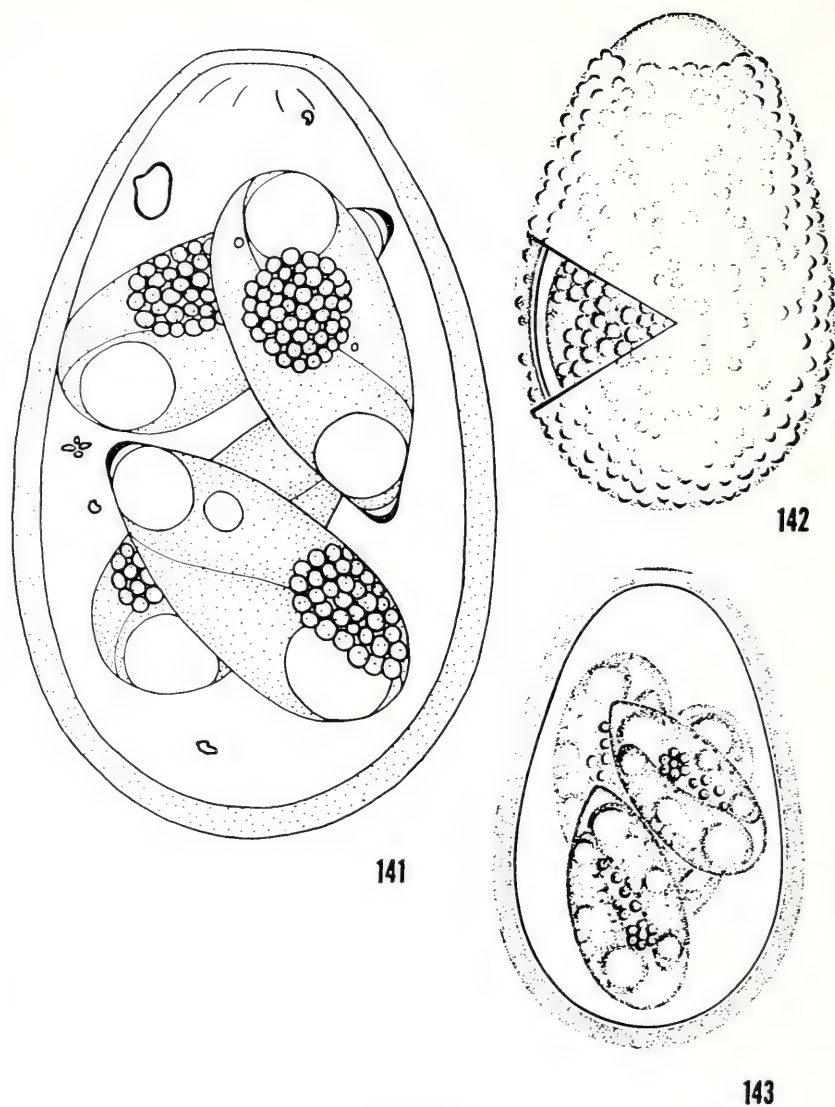
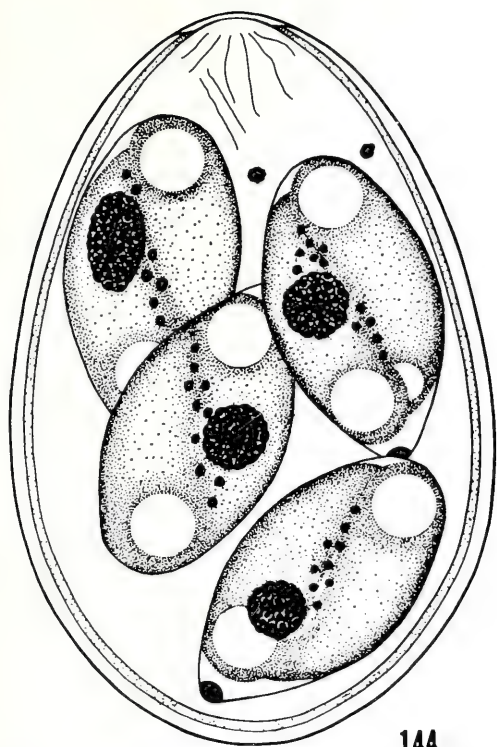
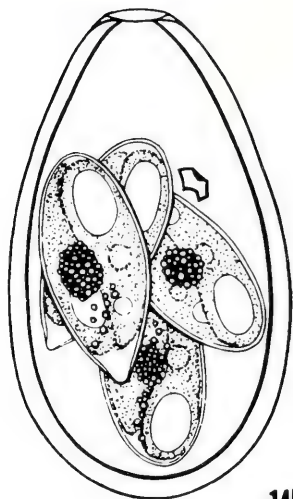


PLATE 32

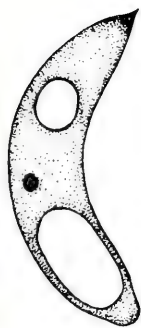
Figs. 141-143. *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus*. Fig. 141. Sporulated oocyst (from Levine and Ivens, 1967). X 2592. Fig. 142. Oocyst with heavily mammillated wall with section removed to show structure of wall and portion of spherical sporont (from Christensen and Porter, 1939). X 1536. Fig. 143. Sporulated oocyst (from Christensen and Porter, 1939). X 1536.



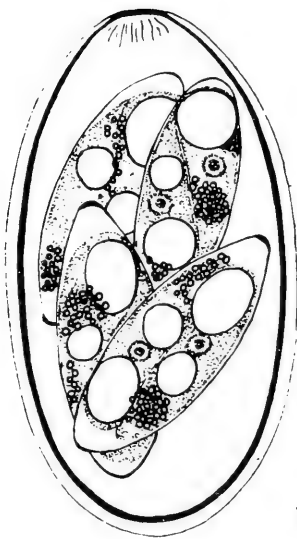
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PLATE 33

Figs. 144-147. *E. auburnensis* Christensen and Porter, 1939. Fig. 144. Sporulated oocyst from *Bos taurus* (from Nyberg and Hammond, 1965). X 2500. Fig. 145. Sporulated oocyst from *Bos taurus* (from Joyner et al., 1966). X 1620. Fig. 146. Sporozoite (from Nyberg and Hammond, 1965). X 2500. Fig. 147. Sporulated oocyst from *Bubalus bubalis* (from Bhatia et al., 1968). X 1500.

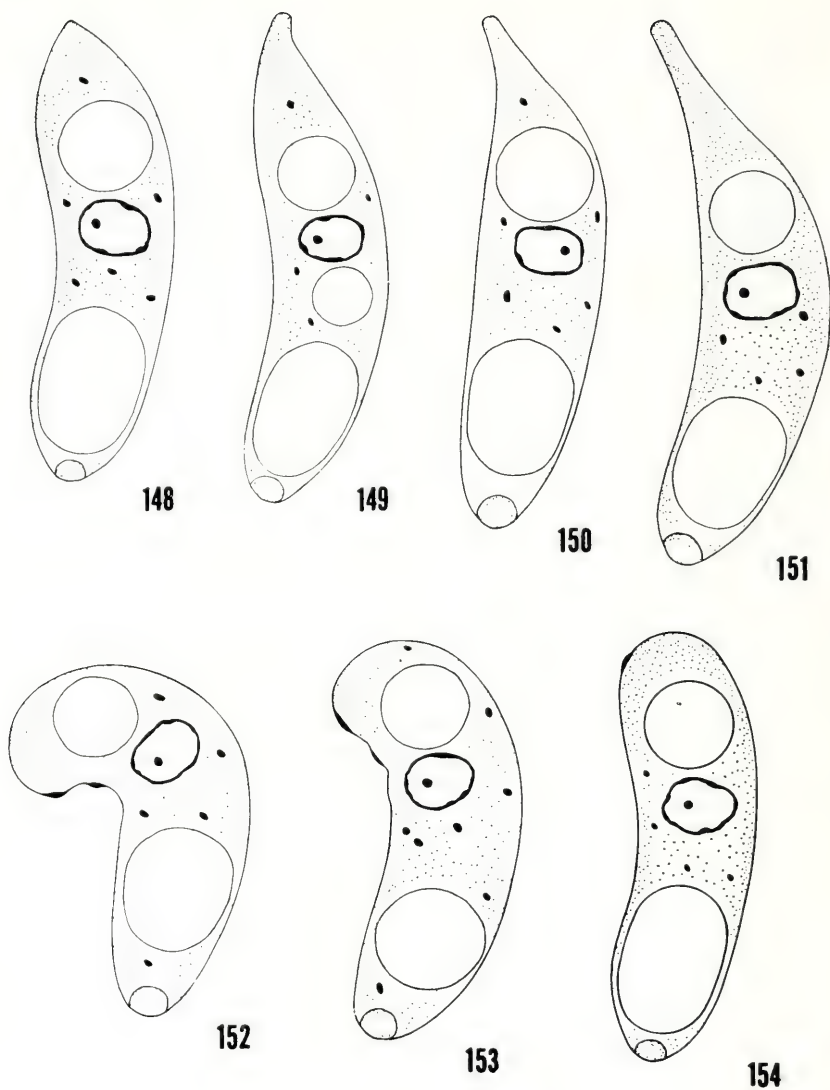


PLATE 34

Figs. 148-154. Sporozoites of *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus* (from Hammond, Chobotar and Ernst, 1968). X 3648. Fig. 148. Broadly lanceolate form. Fig. 149. Intermediate form with 2 anterior refractile bodies. Fig. 150. Intermediate form with one anterior refractile body. Fig. 151. Elongate form. Fig. 152. Fully flexed form showing dark points or ridges at concave surface of bent portion. Fig. 153. Partially flexed form also showing dark points or ridges. Fig. 154. Bluntly rounded form showing a dark point or ridge at one side of anterior region.

All drawings made to scale from photographs of living specimens.

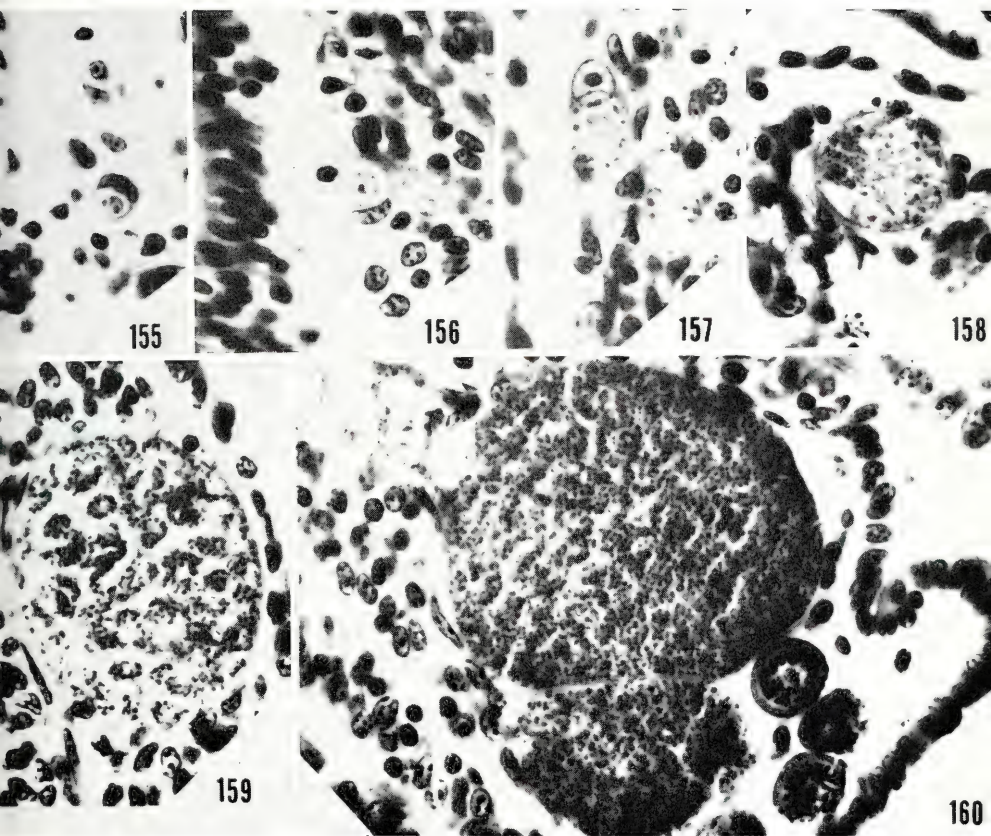


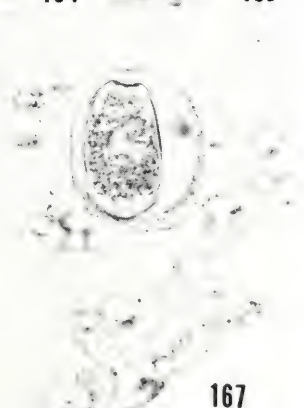
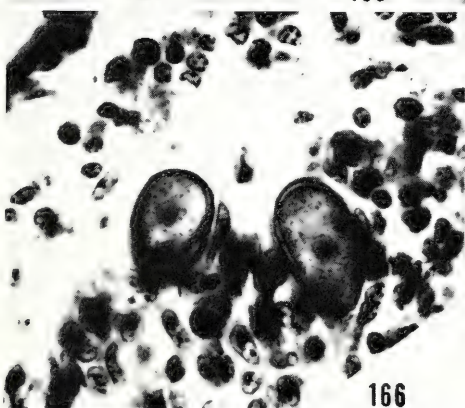
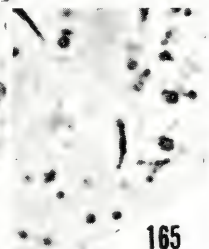
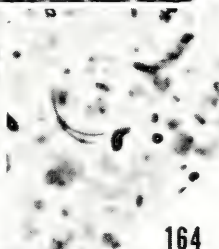
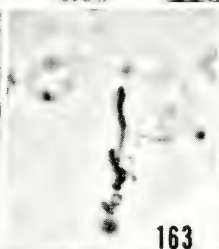
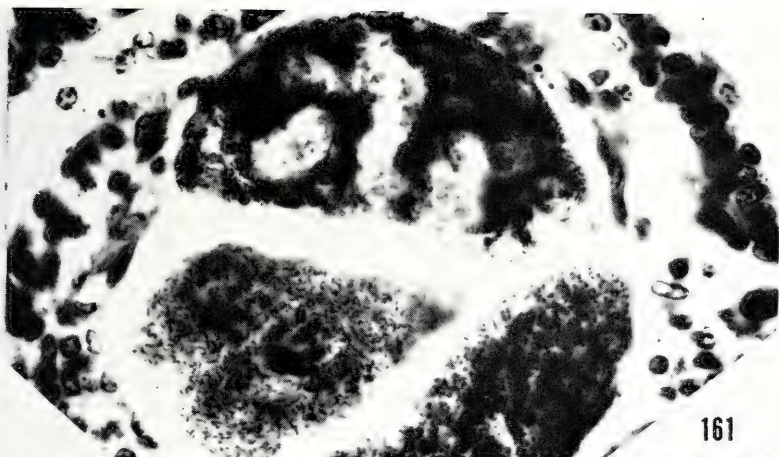
PLATE 35

Figs. 155-160. *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus* (from Hammond, Clark and Miner, 1961). X 579. All figures are specimens in sections of small intestine fixed in Zenker's fluid and stained with iron-hematoxylin. Fig. 155. Early microgametocyte showing 3 nuclei with host cell nucleus at top. Fig. 156. Early macrogamete with host cell nucleus at bottom. Fig. 157. Early microgametocyte showing 10-15 nuclei with host cell nucleus at top. Fig. 158. Intermediate microgametocyte showing 25-30 nuclei with host cell nucleus at top. Fig. 159. Later microgametocyte showing arrangement of nuclei at surface of spheres with host cell nucleus at upper right. Fig. 160. Two later microgametocytes and 4 later macrogametes showing granules arranged to outer wall.

PLATE 36

Figs. 161-167. *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus* (from Hammond, Clark and Miner, 1961). Fig. 161. Three microgametocytes, the one at the top showing microgametes arranged in whorls around residual bodies, and the one in the center with microgametes in random arrangement. X 579. Figs. 162-165. Microgametes each showing flagella. Fresh specimens, phase contrast. X 1448. Fig. 166. Two oocysts in the lamina propria of a villus. X 579. Fig. 167. An oocyst inside its host cell in smear of mucosa. Fresh specimen. X 579.

Except where otherwise stated, all figures are of specimens in sections of small intestine fixed in Zenker's fluid and stained with iron-hematoxylin.



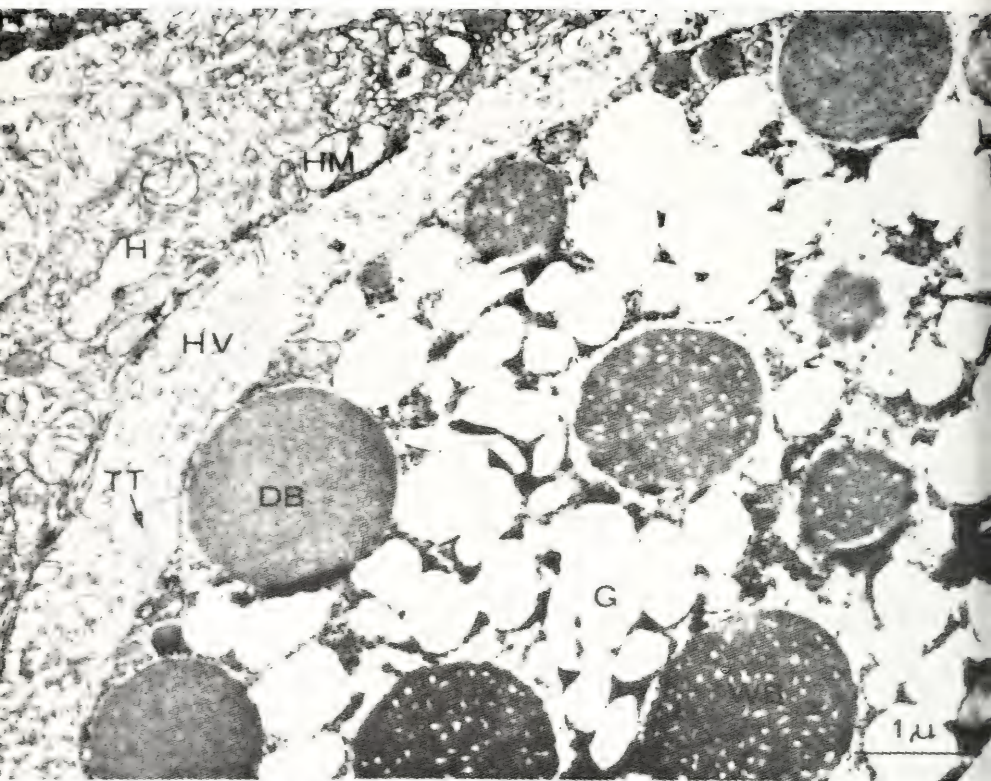


PLATE 37

Fig. 16S. *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus* (from Scholtyssek, Hammond and Ernst, 1966). Electron micrograph of macrogamete within the host cell showing much electron-dense material in the vacuole surrounding the parasite and many mitochondria in the adjacent host cell cytoplasm. X 17,000.

DB, dark bodies; G, glycogen granules; H, host cell; HM, mitochondria; HV, vacuole; TT, transverse sections of microtubules.

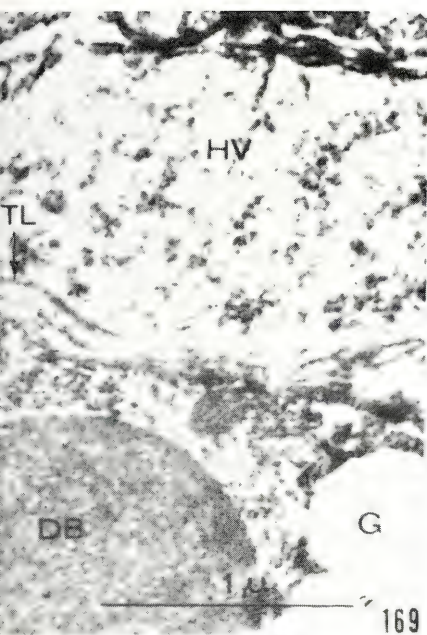


PLATE 38

Figs. 169-170. Electron micrographs of *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus* (from Scholtyseck, Hammond and Ernst, 1966). X 33,000. Fig. 169. Macrogamete within the host cell showing microtubules in longitudinal section at the surface of the macrogamete; these lie in the vacuole surrounding the parasite. Fig. 170. The same as Fig. 169 but showing the microtubules in cross section.

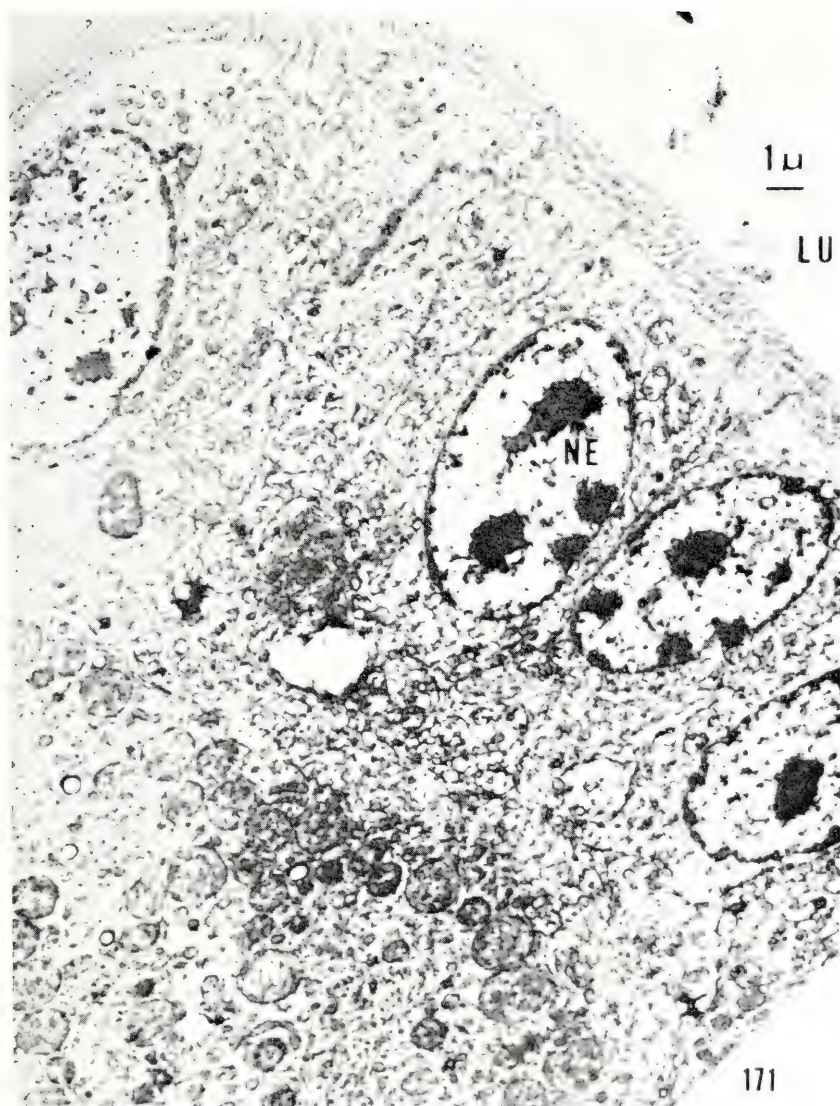
DB, dark bodies; G, glycogen granules; HV, vacuole; TL, longitudinal section of microtubules; TT, transverse sections of microtubules.

PLATE 39

Fig. 171. *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus* (from Hammond, Scholtyseck and Miner, 1967). Electron micrograph showing location of microgametocyte in host cell lying beneath the epithelial layer of a villus. X 4750.

H, host cell; LU, lumen of intestine; N, nucleus; NE, nucleus of epithelial cell layer.

Fixation in OSO_4 , dehydration in acetone and embedding in Vestopal.



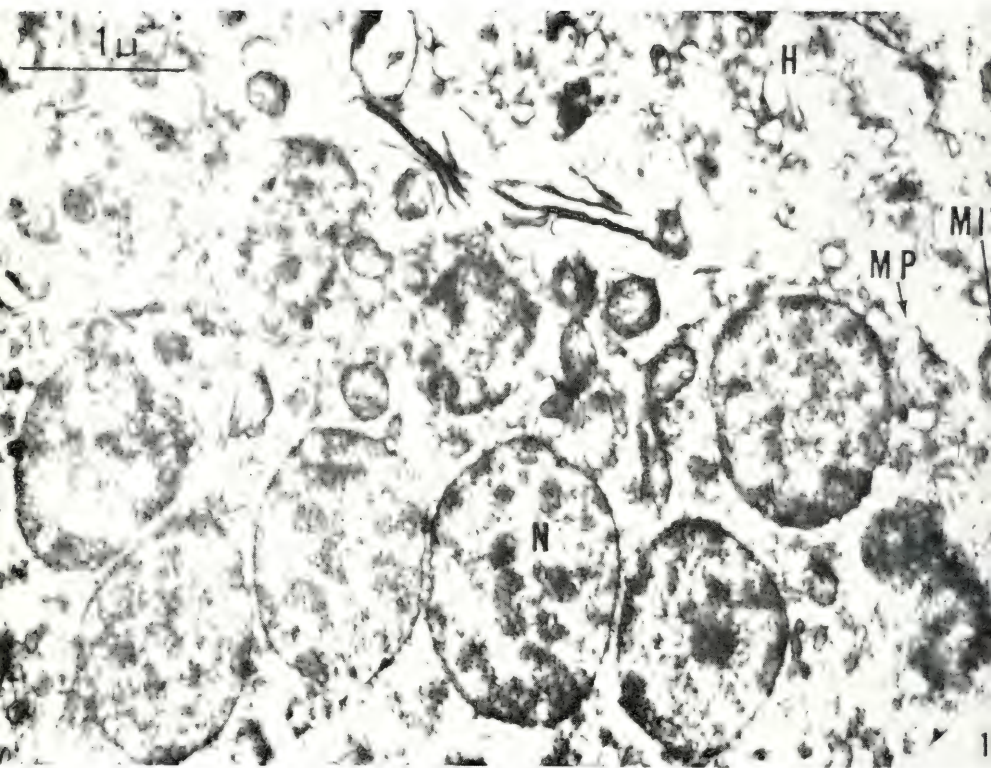


PLATE 40

Fig. 172. *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus* (from Hammond, Scholtyseck and Miner, 1967). Electron micrograph of microgametocyte in host cell. Stage similar to that of Figure 171 (Plate 39), showing detail of area of contact between parasite and host cell. X 22,000.

H, host cell; MIV, mitochondrion of parasite in vacuole of host cell; MP, cell membrane of parasite.

For preparation of tissue, see legend for Plate 39.

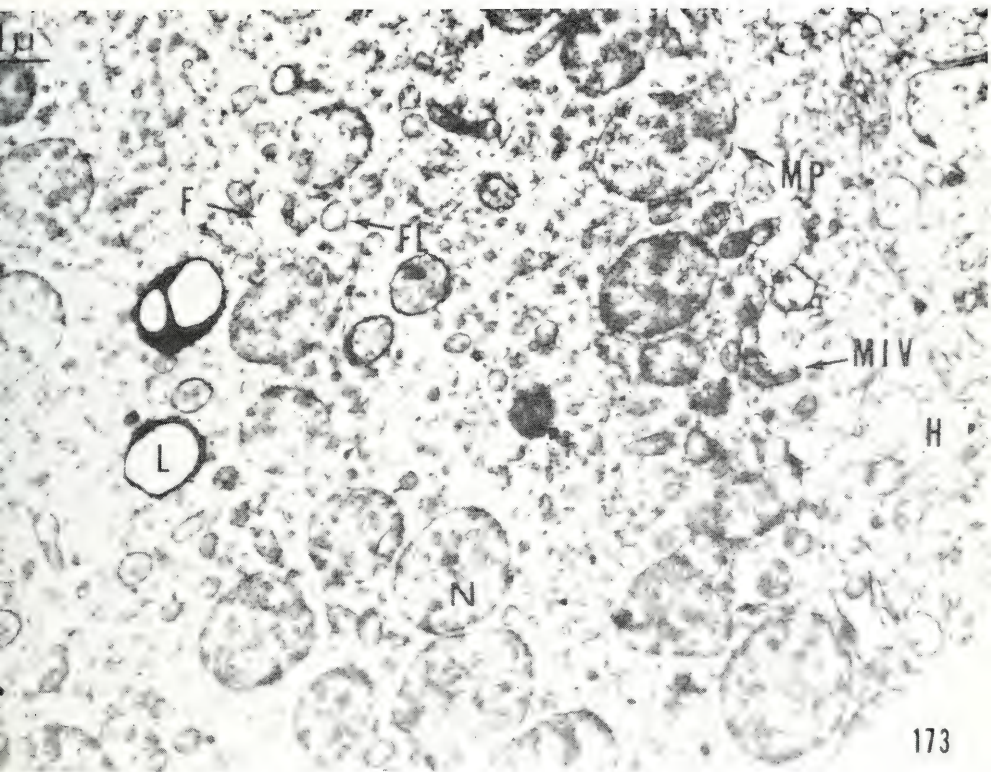


PLATE 41

Fig. 173. *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus* (from Hammond, Scholtyseck and Miner, 1967). Electron micrograph of microgametocyte in host cell, showing detail of furrows and flagella. X 12,000.

F, furrows; FL, flagella; H, host cell; L, lipid inclusion; MIV, mitochondrion of parasite in process of being pinched off into vacuole of the host cell; MP, cell membrane of the parasite; N, nucleus.

For preparation of tissue, see legend for Plate 39.

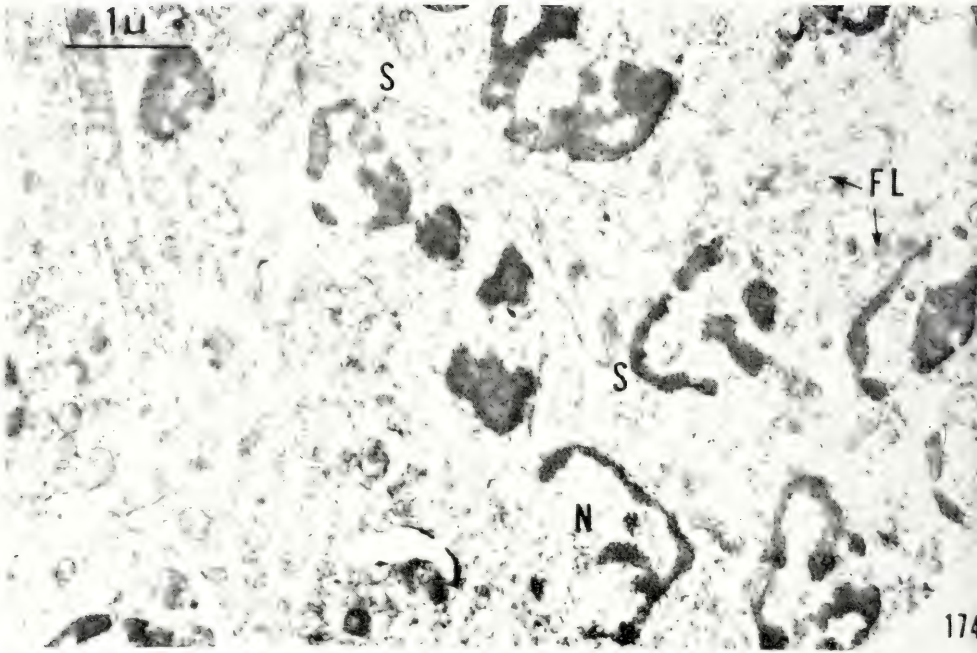


PLATE 42

Fig. 174. *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus* (from Hammond, Scholtyseck and Miner, 1967). Electron micrograph of microgametocyte in host cell. Interior portion of microgametocyte showing flagella in spaces subdividing the protoplasm into small masses. X 17,000.

FL, flagella; N, nucleus; S, spaces.

For preparation of tissue, see legend for Plate 39.

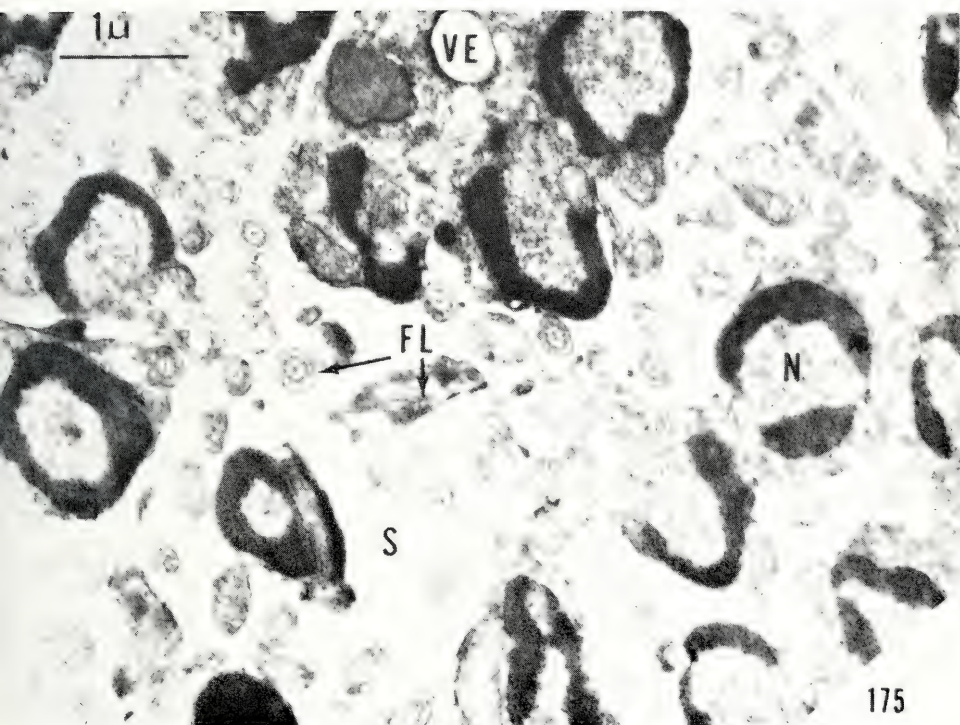


PLATE 43

Fig. 175. *E. auburnensis* Christensen and Porter, 1939 from *Bos taurus* (from Hammond, Scholtyssek and Miner, 1967). Electron micrograph of microgametocyte in host cell. An older stage showing relatively large spaces containing flagella of microgametes. X 17,000.

FL, flagella; N, nucleus; S, spaces; VE, different kinds of vesicles.

For preparation of tissue, see legend for Plate 39.

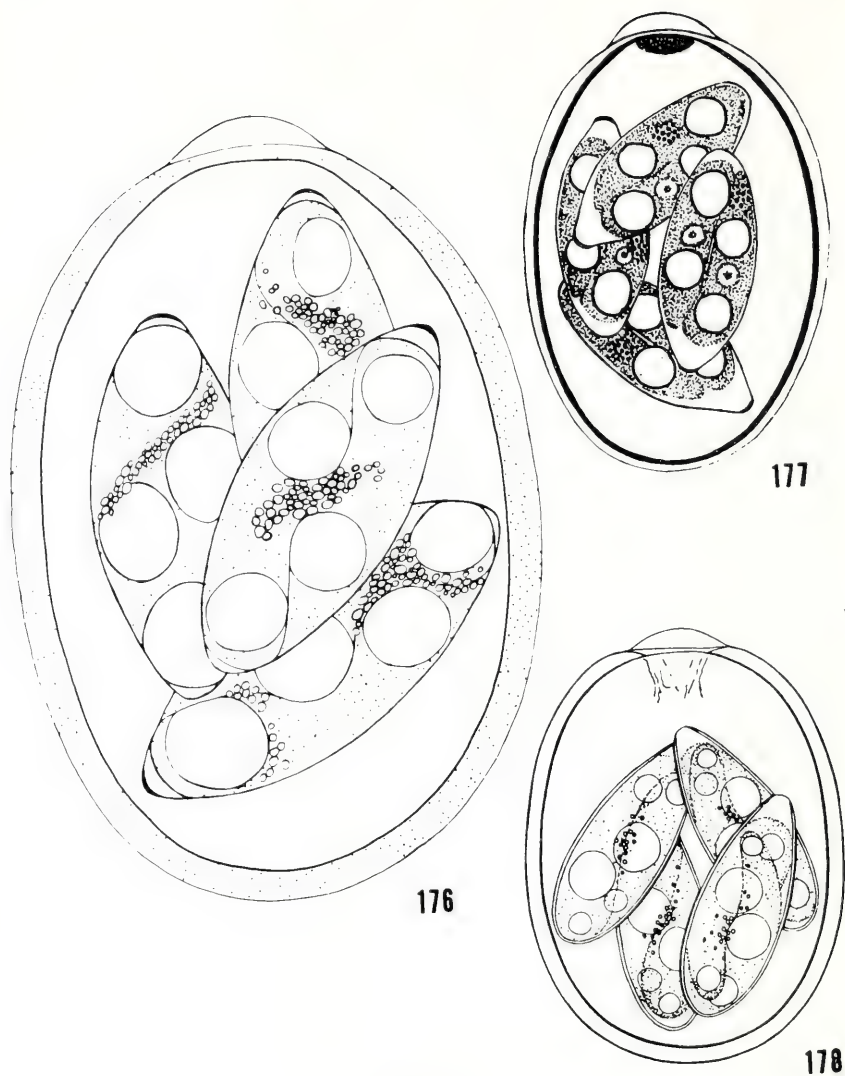


PLATE 44

Figs. 176-178. *E. brasiliensis* Torres and Ramos, 1939. Fig. 176. Sporulated oocyst from *Bos taurus* (from Levine and Ivens, 1967). X 2552. Fig. 177. Sporulated oocyst from *Bubalus bubalis* (from Bhatia et al., 1968). X 1370. Fig. 178. Sporulated oocyst from *Bos taurus* (from Joyner et al., 1966). X 1531.

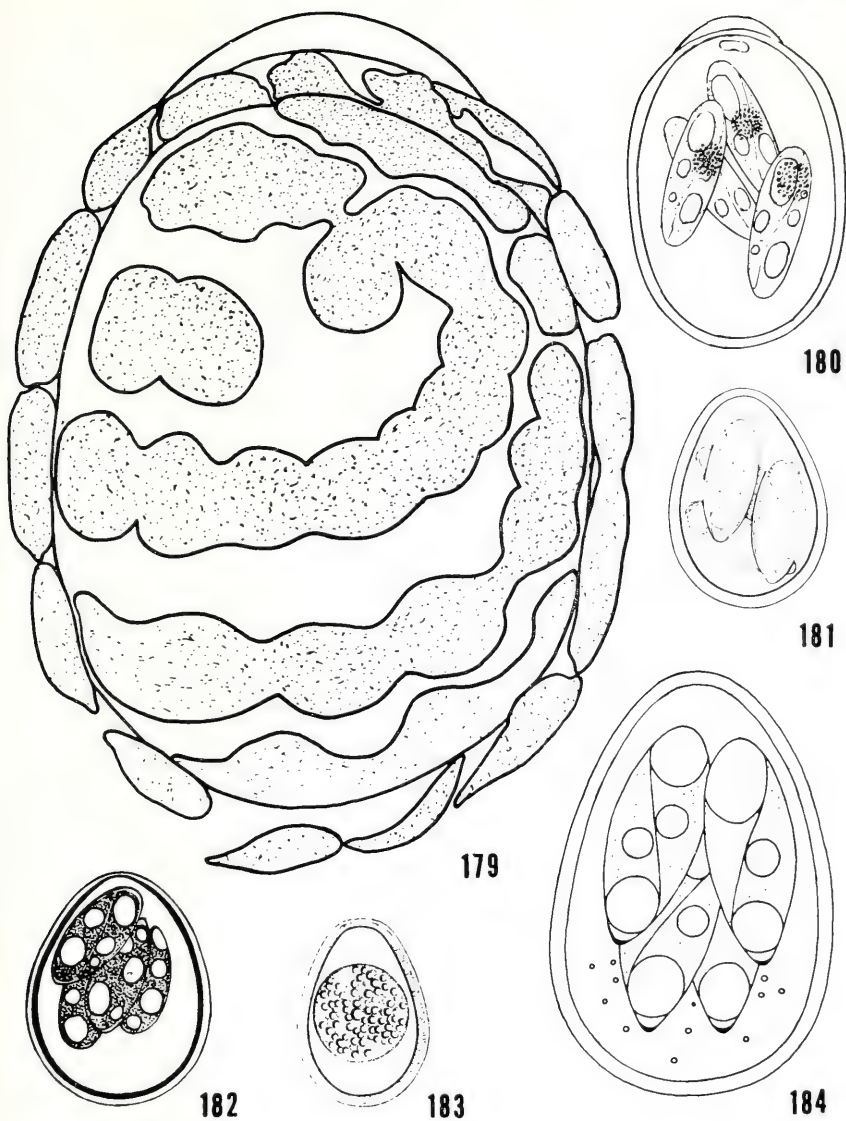


PLATE 45

Figs. 179-180. *E. brasiliensis* Torres and Ramos, 1939 from *Bos taurus*. Fig. 179. Oocyst showing rough wall sloughing off (from Levine and Ivens, 1967). X 2592. Fig. 180. Sporulated oocyst (from Supperer, 1952 — cited as *E. boehmi*). X 1104.

Figs. 181-184. *E. alabamensis* Christensen, 1941. Fig. 181. Sporulated oocyst from *Bos taurus* (from Joyner et al., 1966). X 1560. Fig. 182. Sporulated oocyst from *Bubalus bubalis* (from Bhatia et al., 1968). X 1440. Fig. 183. Unsporulated oocyst from *Bos taurus* (from Christensen, 1941). X 1296. Fig. 184. Sporulated oocyst from *Bos taurus* (from Levine and Ivens, 1967). X 2592.

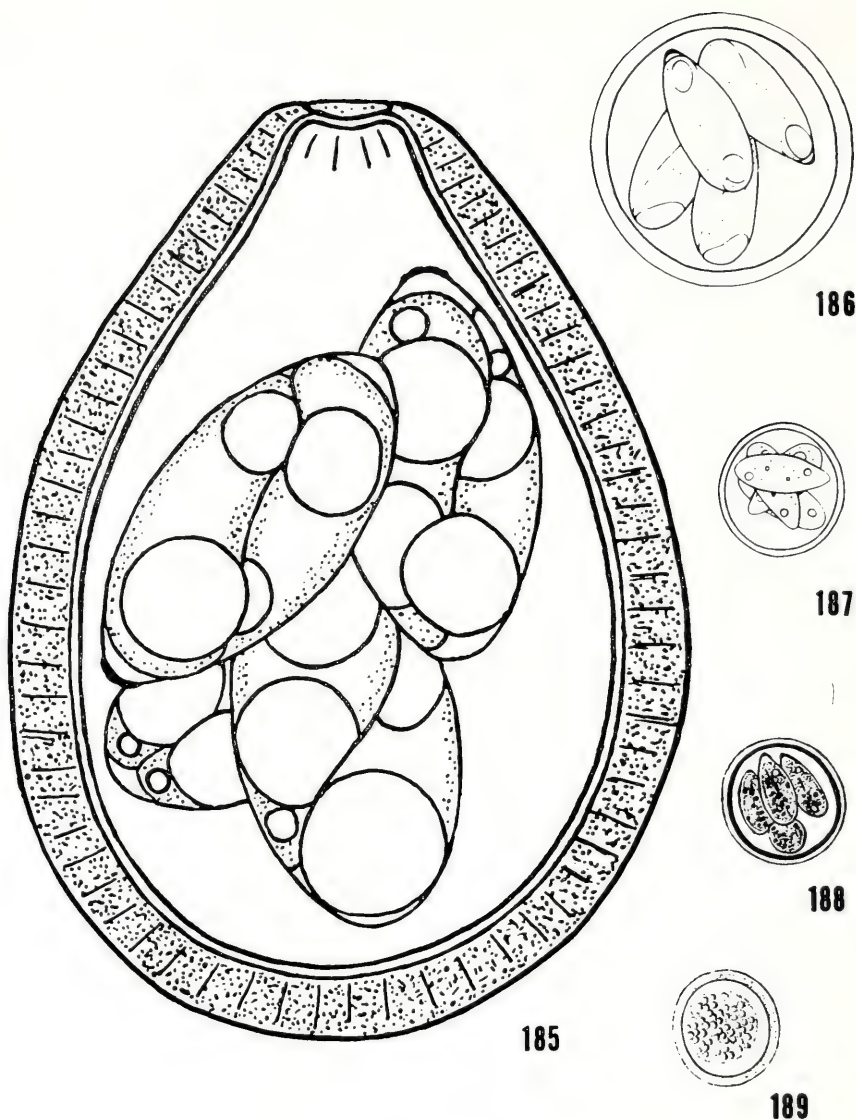
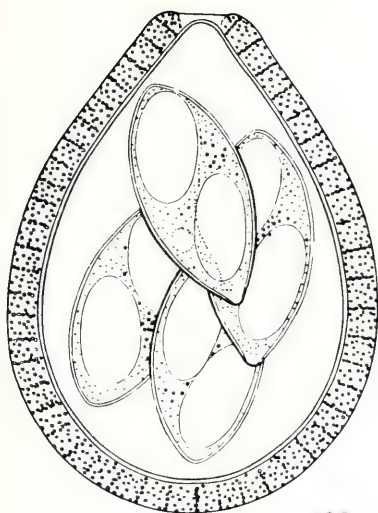


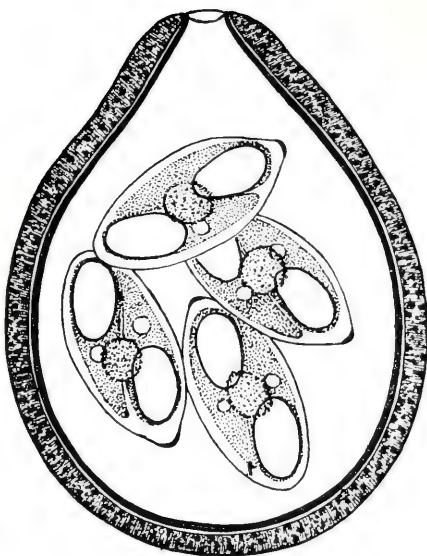
PLATE 46

Fig. 185. *E. bukidnonensis* Tubangui, 1931 from *Bos taurus* (from Levine and Ivens, 1967). X 2700.

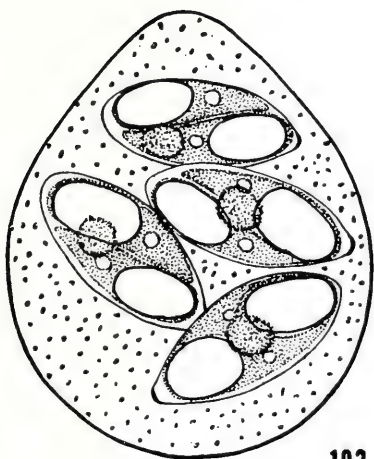
Fig. 186-189. *E. subspherica* Christensen, 1941. Fig. 186. Sporulated oocyst from *Bos taurus* (from Levine and Ivens, 1967). X 2700. Fig. 187. Sporulated oocyst from *Bos taurus* (from Joyner et al., 1966). X 1625. Fig. 188. Sporulated oocyst from *Bubalus bubalis* (from Bhatia et al., 1968). X 1500. Fig. 189. Unsporulated oocyst from *Bos taurus* (from Christensen, 1941). X 1350.



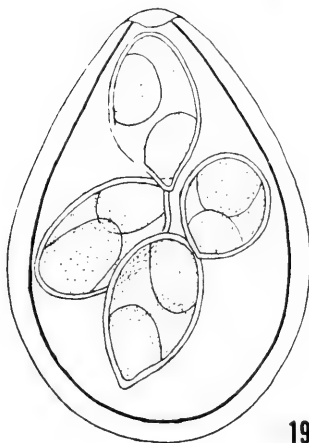
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Figs. 190-193. *E. bukidnonensis* Tubangui, 1931. Fig. 190. Sporulated oocyst from *Bos taurus* (from Joyner et al., 1966). X 1436. Fig. 191. Sporulated oocyst from *Bubalus bubalis* (from Bhatia et al., 1968). X 1418. Fig. 192. Sporulated oocyst without outer wall (from Bhatia et al., 1968). X 1418. Fig. 193. Sporulated oocyst from *Bos indicus* (from Tubangui, 1931). X 1058.

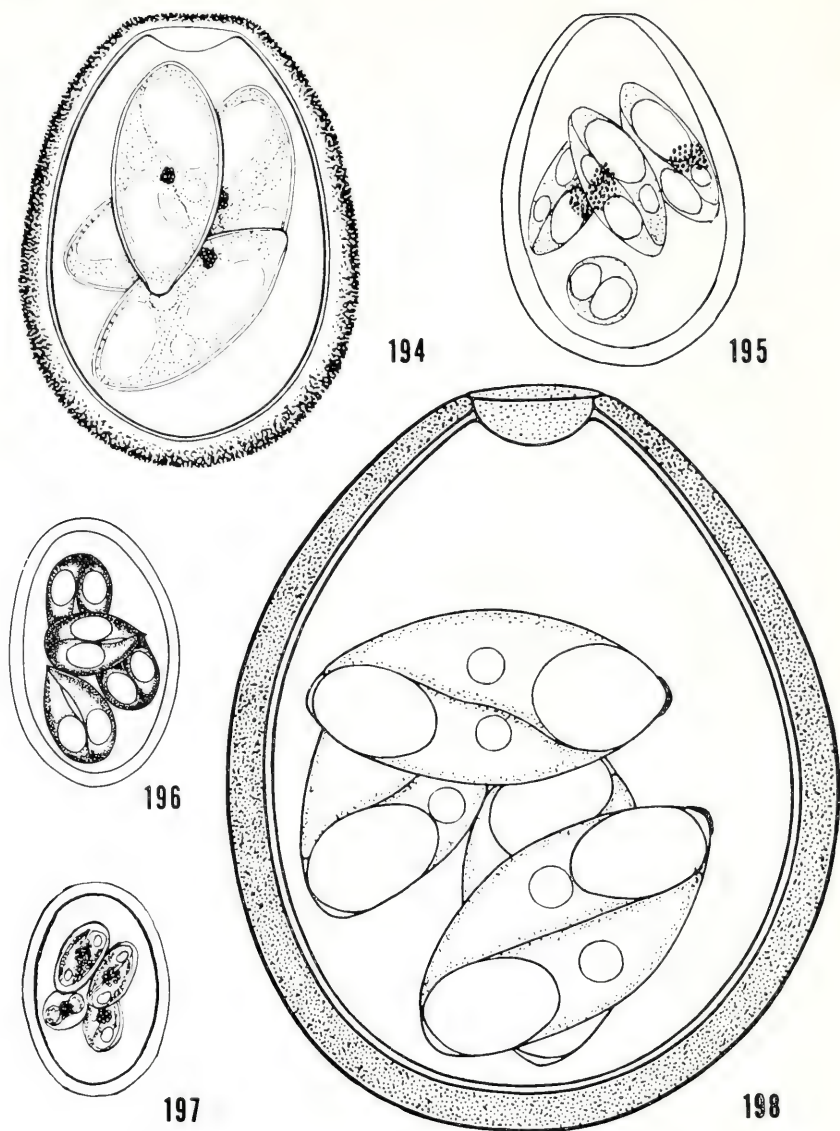


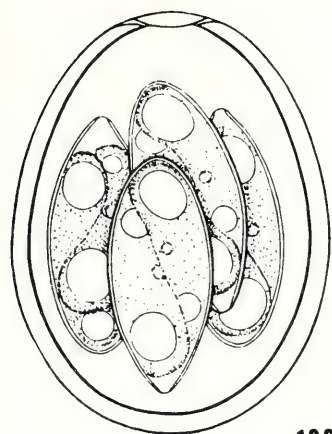
PLATE 48

Figs. 194-195. *E. pellita* Supperer, 1952 from *Bos taurus*. Fig. 194. Sporulated oocyst (from Joyner et al., 1966). X 1584. Fig. 195. Sporulated oocyst (from Supperer, 1952). X 1170.

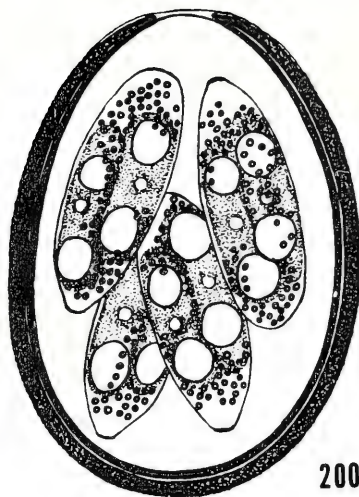
Fig. 196. *E. talboti* Prasad and Narayan, 1963 from *Alcelaphus cokei* (from Prasad and Narayan, 1963). X 878.

Fig. 197. *E. connochaetei* n. sp. from *Connochaetes gnu* (from Prasad, 1960 — cited as *E. ellipsoidalis*). X 829.

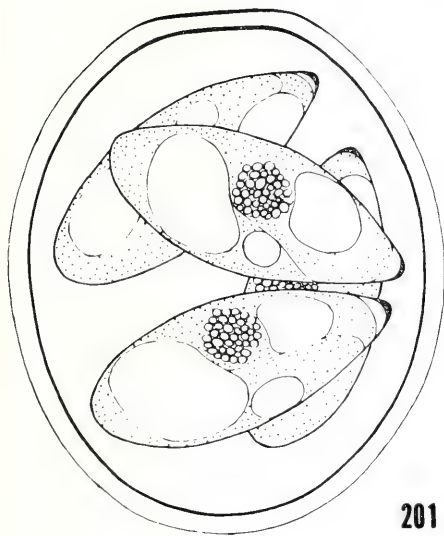
Fig. 198. *E. wyomingensis* Huizinga and Winger, 1942 from *Bos taurus* (from Levine and Ivens, 1967). X 2633.



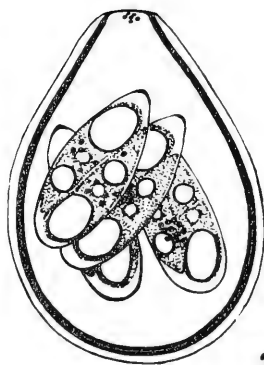
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Figs. 199-200. *E. wyomingensis* Huizinga and Winger, 1942. Fig. 199. Sporulated oocyst from *Bos taurus* (from Joyner et al., 1966). X 1620. Fig. 200. Sporulated oocyst from *Bubalus bubalis* (from Bhatia et al., 1968). X 1500.

Fig. 201. *E. illinoisensis* Levine and Ivens, 1967 from *Bos taurus* (from Levine and Ivens, 1967). X 2700.

Fig. 202. *E. bareillyi* Gill, Chhabra and Lall, 1963 from *Bubalus bubalis* (from Bhatia et al., 1968). X 1500.

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Fig. 203. *E. gorgonis* Prasad, 1960 from *Gorgon taurinus* (from Prasad, 1960). X 1900.

Fig. 204. *E. walleri* Prasad, 1960 from *Litocranius walleri* (from Prasad, 1960). X 850.

Figs. 205-206. *E. impalae* Prasad and Narayan, 1963 from *Aepyceros melampus*. Fig. 205. Sporulated oocyst (from Prasad and Narayan, 1963). X 900.
Fig. 206. Sporulated oocyst (from Bigalke, 1964). X 1430.

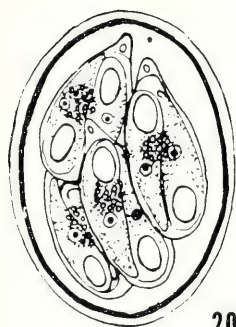
Fig. 207. *E. elegans* Yakimoff, Gousseff and Rastegaieff, 1932 from *Gazella subgutturosa* (from Yakimoff, Gousseff and Rastegaieff, 1932b).)

Fig. 208. *E. saiga* Svanbaev, 1958 from *Saiga tatarica* (from Svanbaev, 1958). X 800.

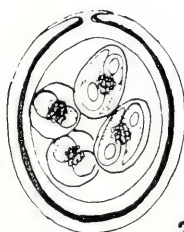
Fig. 209. *E. rupicaprae* Galli-Valerio, 1924 from *Rupicapra rupicapra* (from Yakimoff and Matschoulsky, 1940).

Figs. 210-211. *E. riedmuelleri* Yakimoff and Matschoulsky, 1940 emend. from *Rupicapra rupicapra* (from Yakimoff and Matschoulsky, 1940).

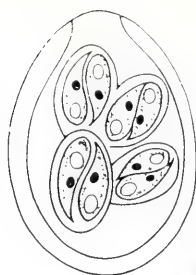
Fig. 212. *E. yakimoffmatschoulskyi* Supperer and Kutzer, 1961 emend. from *Rupicapra rupicapra* (from Supperer and Kutzer, 1961). X 1230.



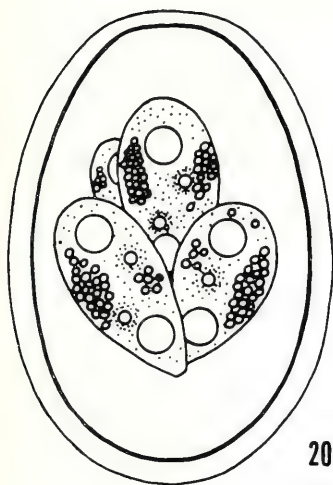
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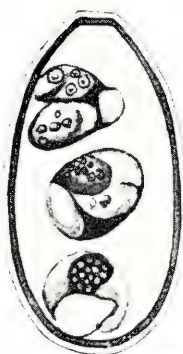
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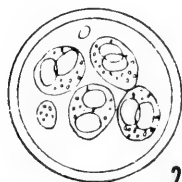
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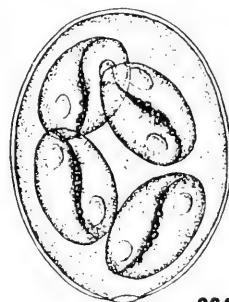
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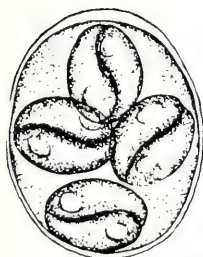
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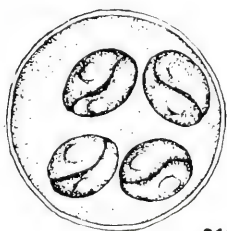
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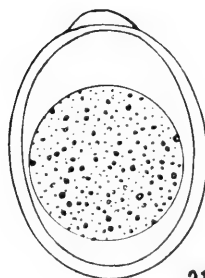
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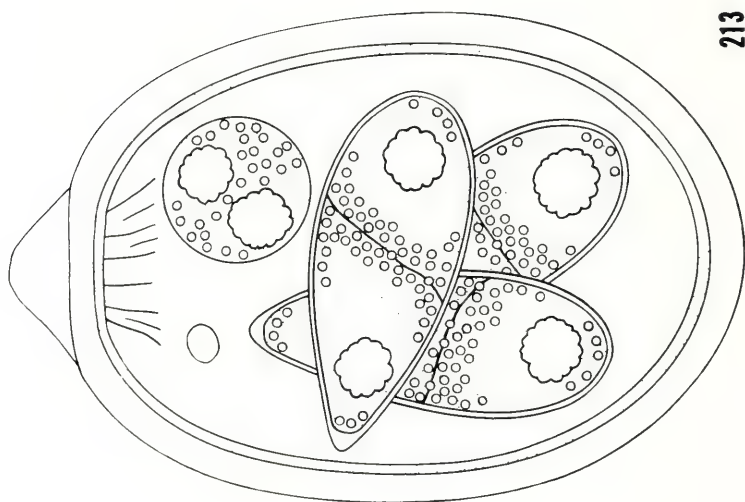
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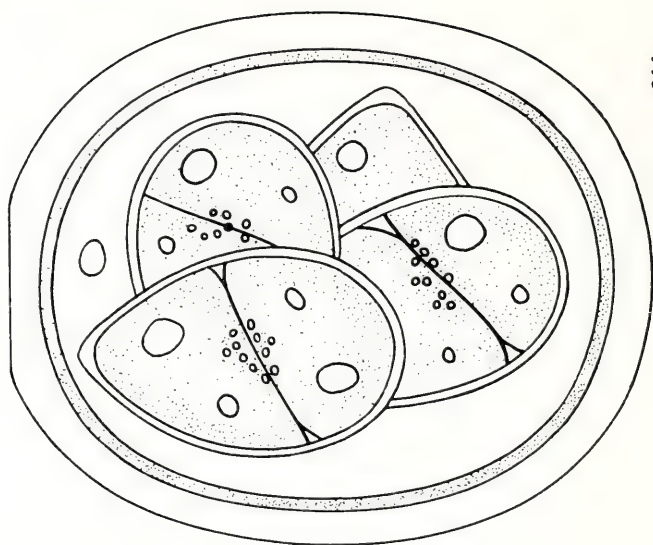
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PLATE 51

Fig. 213. *E. ernsti* Todd and O'Gara, 1968 from *Oreamnos americanus* (from Todd and O'Gara, 1968). X 2800.

Fig. 214. *E. montanaensis* Todd and O'Gara, 1968 from *Oreamnos americanus* (from Todd and O'Gara, 1968). X 4200.

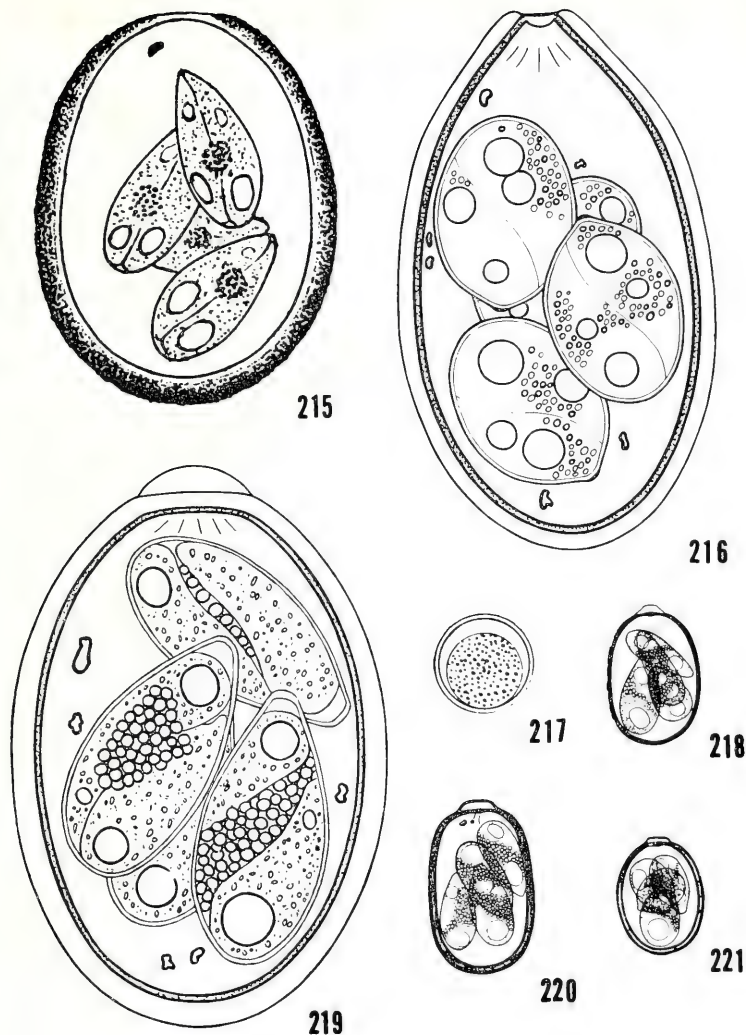


PLATE 52

Fig. 215. *E. suppereri* Kutzer, 1964 from *Rupicapra rupicapra* (from Kutzer, 1964). X 1166.

Fig. 216. *E. oreamni* Shah and Levine, 1964 from *Oreamnos americanus* (from Shah and Levine, 1964). X 2405.

Fig. 217. *E. alpina* Supperer and Kutzer, 1961 from *Rupicapra rupicapra* (from Supperer and Kutzer, 1961). X 1156.

Figs. 218-221. *E. arloingi* (Marotel, 1905) Martin, 1909 from *Capra hircus*.
 Fig. 218. Sporulated oocyst (from Chevalier, 1966). X 648. Fig. 219. Sporulated oocyst (from Levine, Ivens and Fritz, 1962). X 2405. Fig. 220. Sporulated oocyst (from Chevalier, 1966 — cited as *E. ahsata*). X 648. Fig. 221. Sporulated oocyst (from Chevalier, 1966 — cited as *E. crandallii*). X 648.

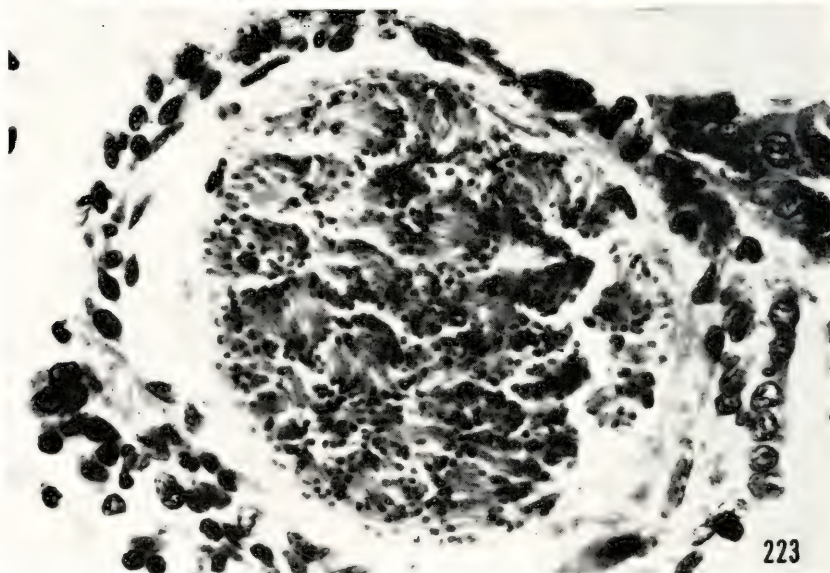
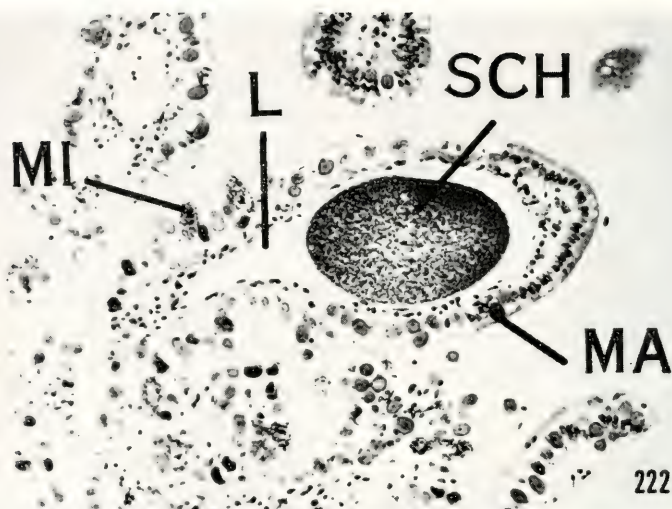


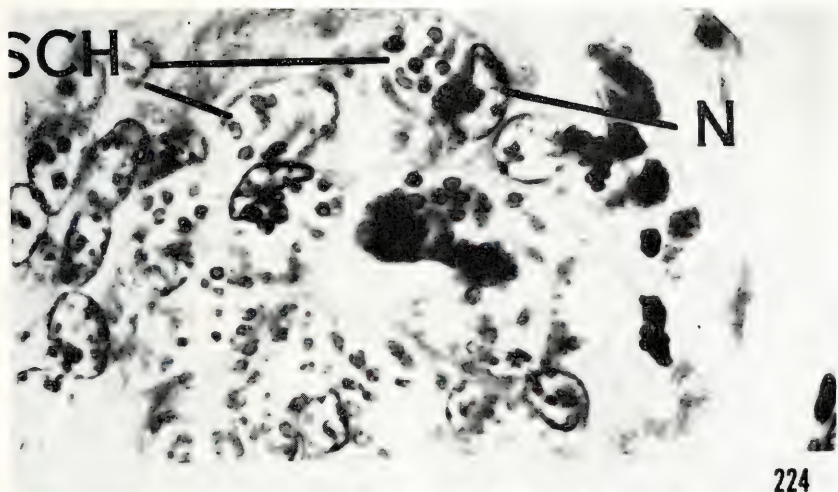
PLATE 53

Figs. 222-223. Possibly *E. arloingi* (Marotel, 1905) Martin, 1909 from *Capra hircus* (from Levine, Ivens and Fritz, 1962). Fig. 222. Immature giant schizont in lacteal of villus in the jejunum. X 118.

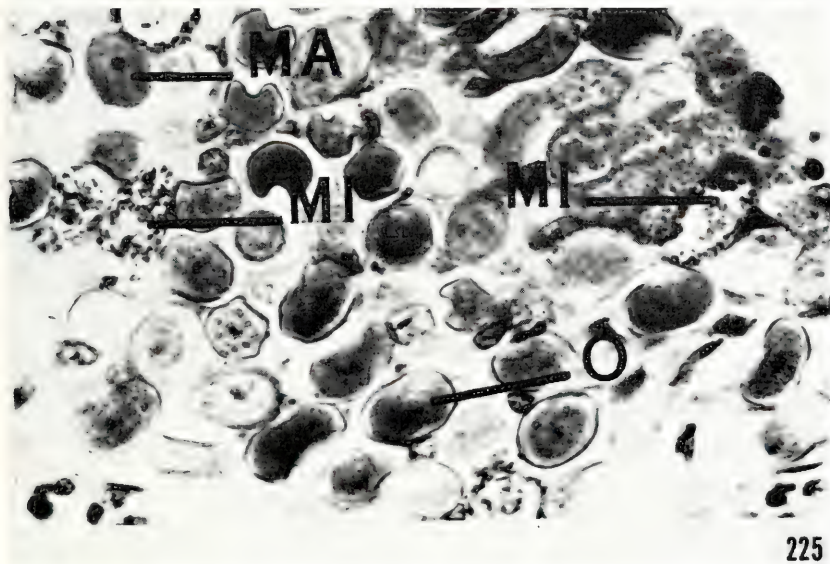
L, lacteal containing precipitated lymph; MA, macrogamete; MI, microgametocyte; SCH, schizont.

Fig. 223. Mature giant schizont in lacteal in jejunum. Note clusters of merozoites. X 531.

Fixed in formalin and stained with Harris hematoxylin and eosin.



224



225

PLATE 54

Figs. 224-225. Possibly *E. arloingi* (Marotel, 1905) Martin, 1909 from *Capra hircus* (from Levine, Ivens and Fritz, 1962). Fig. 224. Small schizonts in epithelial cells in the glands of the jejunum. X 1110.

N, host cell nucleus; SCH, schizont.

Fig. 225. Sexual stages in epithelial cells of villus in the duodenum. X 483.

MA, macrogamete; MI, microgametocyte; O, oocyst.

Fixed in formalin and stained with Harris hematoxylin and eosin.

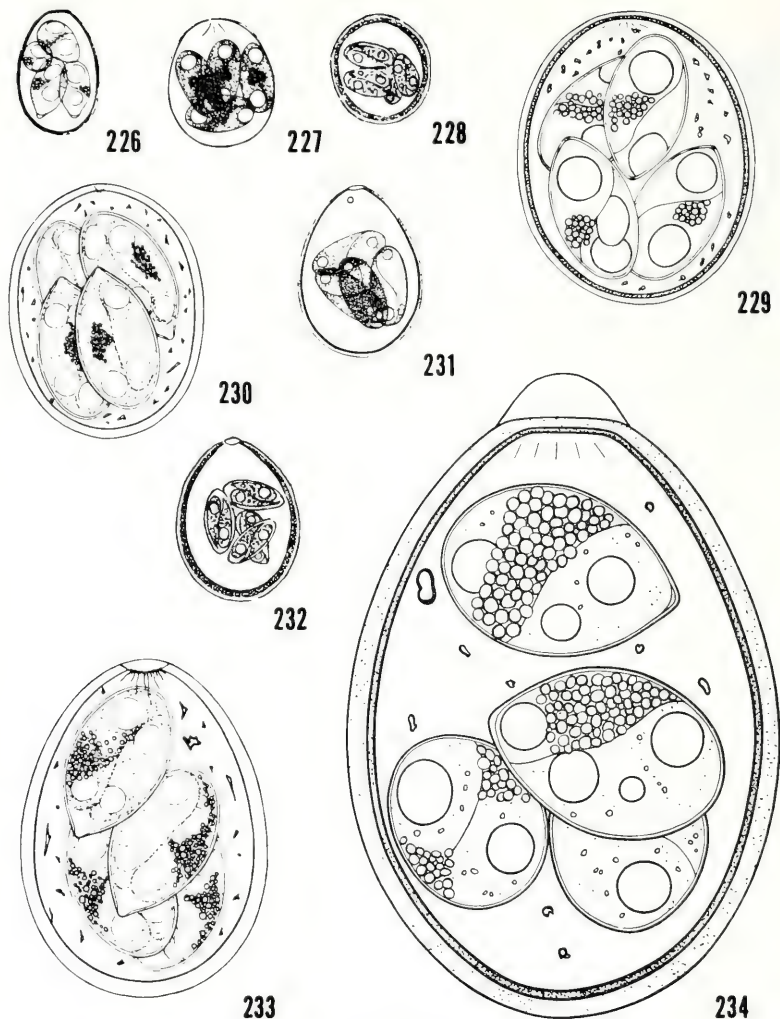


PLATE 55

Figs. 226-230. *E. ninakohlyakimovae* Yakimoff and Rastegaieff, 1930 emend. Levine, 1961. Fig. 226. Sporulated oocyst from *Capra hircus* (from Chevalier, 1966). X 623. Fig. 227. Sporulated oocyst from *Ovis aries* (from Chevalier, 1965). X 712. Fig. 228. Sporulated oocyst from *Capra hircus* (from Singh, 1964). X 668. Fig. 229. Sporulated oocyst from *Ovis aries* (from Shah, 1963). X 1691. Fig. 230. Sporulated oocyst from *Ovis aries* (from Joyner et al., 1966). X 1446.

Figs. 231-233. *E. faurei* (Moussu and Marotel, 1902) Martin, 1909. Fig. 231. Sporulated oocyst from *Ovis aries* (from Chevalier, 1965). X 712. Fig. 232. Sporulated oocyst from *Capra hircus* (from Singh, 1964). X 668. Fig. 233. Sporulated oocyst from *Ovis aries* (from Joyner et al., 1966). X 1446. Fig. 234. *E. christenseni* Levine, Ivens and Fritz, 1962 from *Capra hircus* (from Levine, Ivens and Fritz, 1962). X 2314.

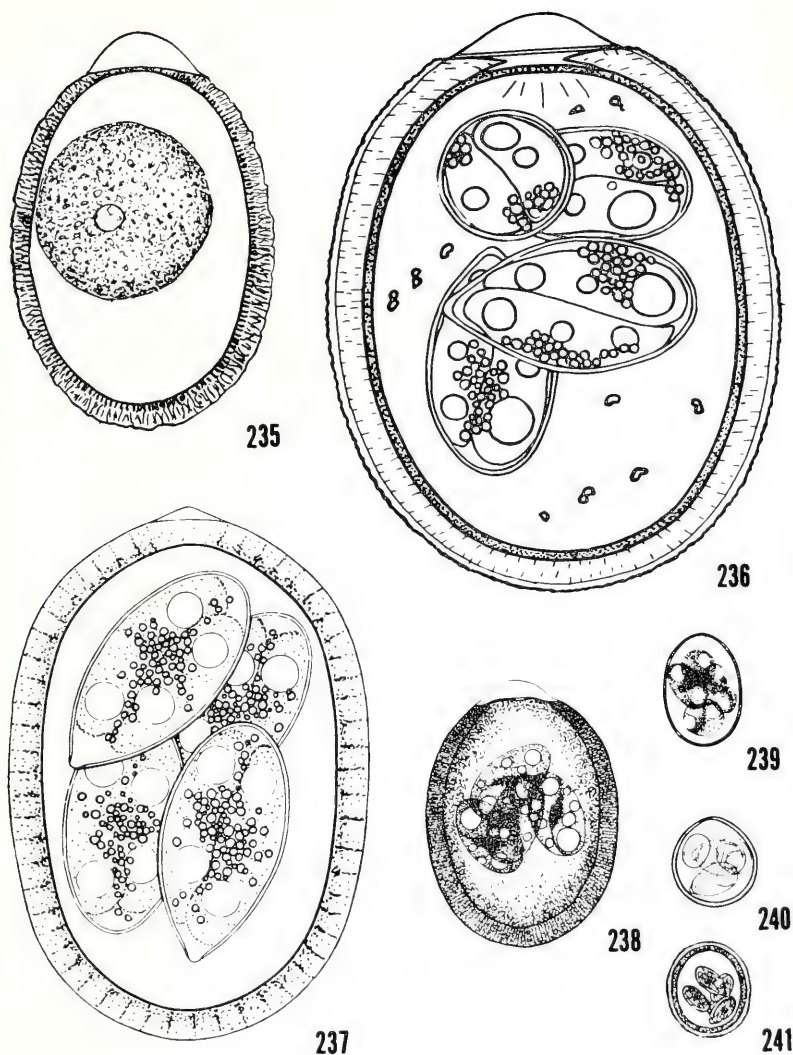


PLATE 56

Figs. 235-238. *E. intricata* Spiegl, 1925 from *Ovis aries*. Fig. 235. Sporulated oocyst (from Balozet, 1932a). X 1007. Fig. 236. Sporulated oocyst (from Shah, 1963). X 1739. Fig. 237. Sporulated oocyst (from Joyner et al., 1966). X 1487. Fig. 238. Sporulated oocyst (from Chevalier, 1965). X 732.

Figs. 239-241. *E. parva* Kotlan, Moesy and Vajda, 1929. Fig. 239. Sporulated oocyst from *Ovis aries* (from Chevalier, 1965). X 732. Fig. 240. Sporulated oocyst from *Capra hircus* (from Chevalier, 1966). X 641. Fig. 241. Sporulated oocyst from *Capra hircus* (from Singh, 1964). X 686.

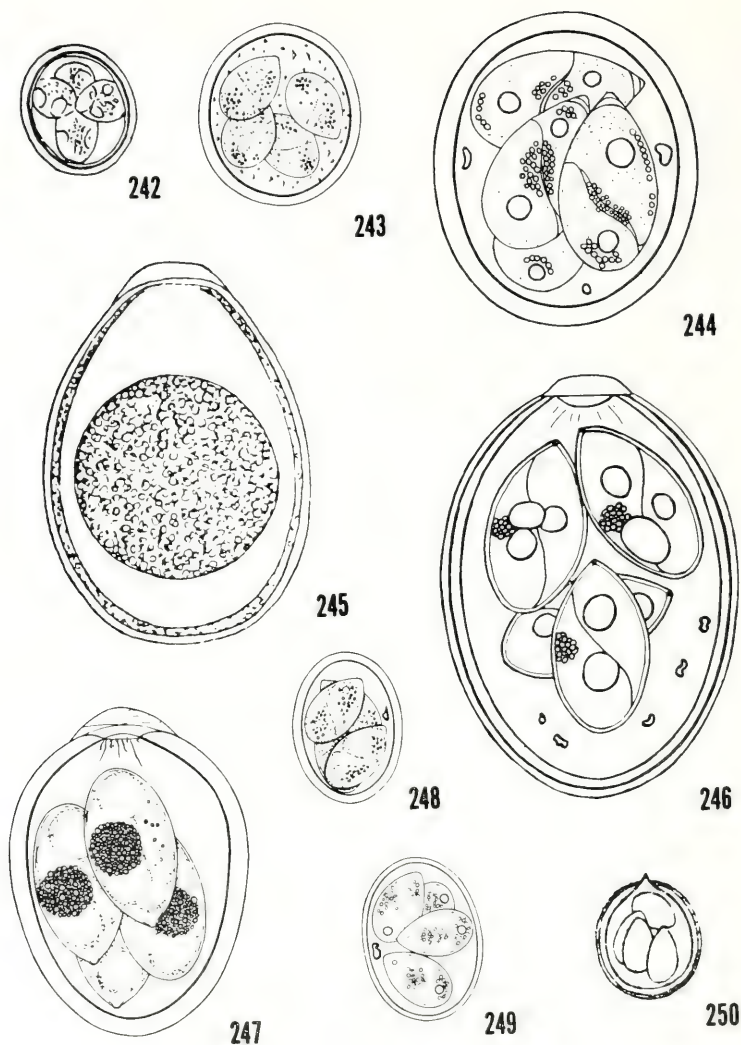


PLATE 57

Figs. 242-244. *E. parva* Kotlan, Moesy and Vajda, 1929 from *Ovis aries*. Fig. 242. Sporulated oocyst (from Balozet, 1932a). X 990. Fig. 243. Sporulated oocyst (from Joyner et al., 1966). X 1463. Fig. 244. Sporulated oocyst (from Kamalapur, 1961). X 2340.

Fig. 245. *Eimeria* sp. Patyk, 1965 from *Ovis aries* (from Patyk, 1965). X 1638.

Figs. 246-247. *E. granulosa* Christensen, 1938 from *Ovis aries*. Fig. 246. Sporulated oocyst (from Shah, 1963). X 1710. Fig. 247. Sporulated oocyst (from Joyner et al., 1966). X 1463.

Figs. 248-249. *E. pallida* Christensen, 1938 from *Ovis aries*. Fig. 248. Sporulated oocyst (from Joyner et al., 1966). X 1463. Fig. 249. Sporulated oocyst (from Shah, 1963). X 1710.

Fig. 250. *E. hawkinsi* Ray, 1952 from *Ovis aries* (from Ray, 1961).

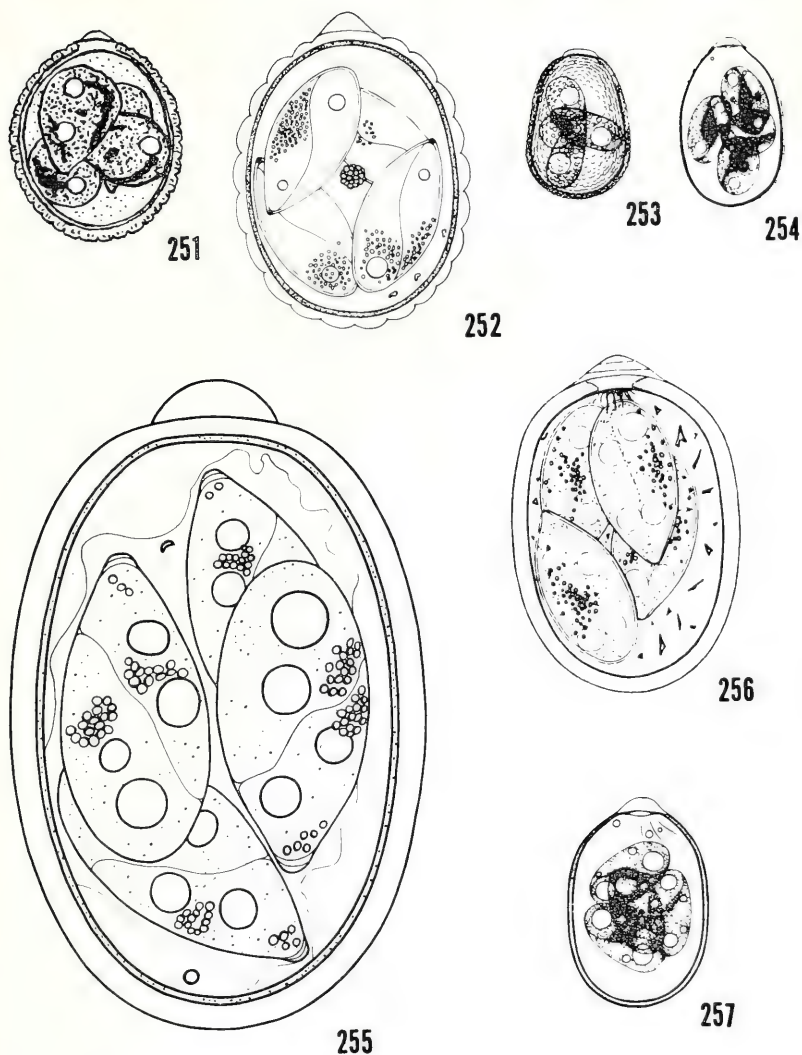


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Figs. 251-253. *E. punctata* Landers, 1955. Fig. 251. Sporulated oocyst from *Ovis aries* (from Landers, 1952 — cited as *E. honessi*). X 2097. Fig. 252. Sporulated oocyst from *Ovis aries* (from Shah, 1963). X 1815. Fig. 253. Sporulated oocyst from *Capra hircus* (from Chevalier, 1966). X 669.

Figs. 254-256. *E. ovina* n. sp. from *Ovis aries*. Fig. 254. Sporulated oocyst (from Chevalier, 1965 — cited as *E. arloingi*). X 764. Fig. 255. Sporulated oocyst (from Kamalapur, 1961 — cited as *E. arloingi*). X 2483. Fig. 256. Sporulated oocyst (from Joyner et al., 1966 — cited as *E. arloingi*). X 1552. Fig. 257. *E. ahsata* Honess, 1942 from *Ovis aries* (from Chevalier, 1965). X 764.

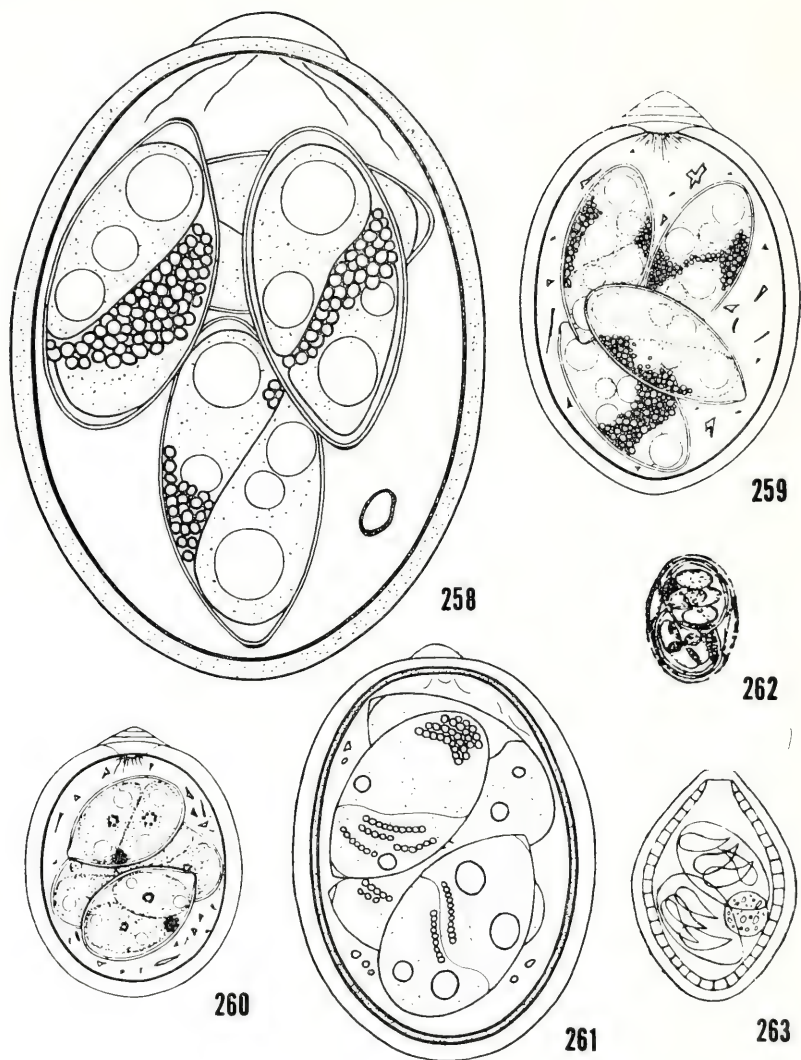


PLATE 59

Figs. 258-259. *E. ahsata* Honess, 1942 from *Ovis aries*. Fig. 258. Sporulated oocyst (from Levine et al., 1962). X 2405. Fig. 259. Sporulated oocyst (from Joyner et al., 1966). X 1503.

Figs. 260-261. *E. crandallii* Honess, 1942 from *Ovis aries*. Fig. 260. Sporulated oocyst (from Joyner et al., 1966). X 1503. Fig. 261. Sporulated oocyst (from Kamalapur, 1961). X 2405.

Fig. 262. *I. orlovi* Tsygankov, 1950 from a camel (from Tsygankov, 1950). X 555.

Fig. 263. *I. capreoli* Svanbaev, 1958 from *Capreolus capreolus* (from Svanbaev, 1958). X 740.

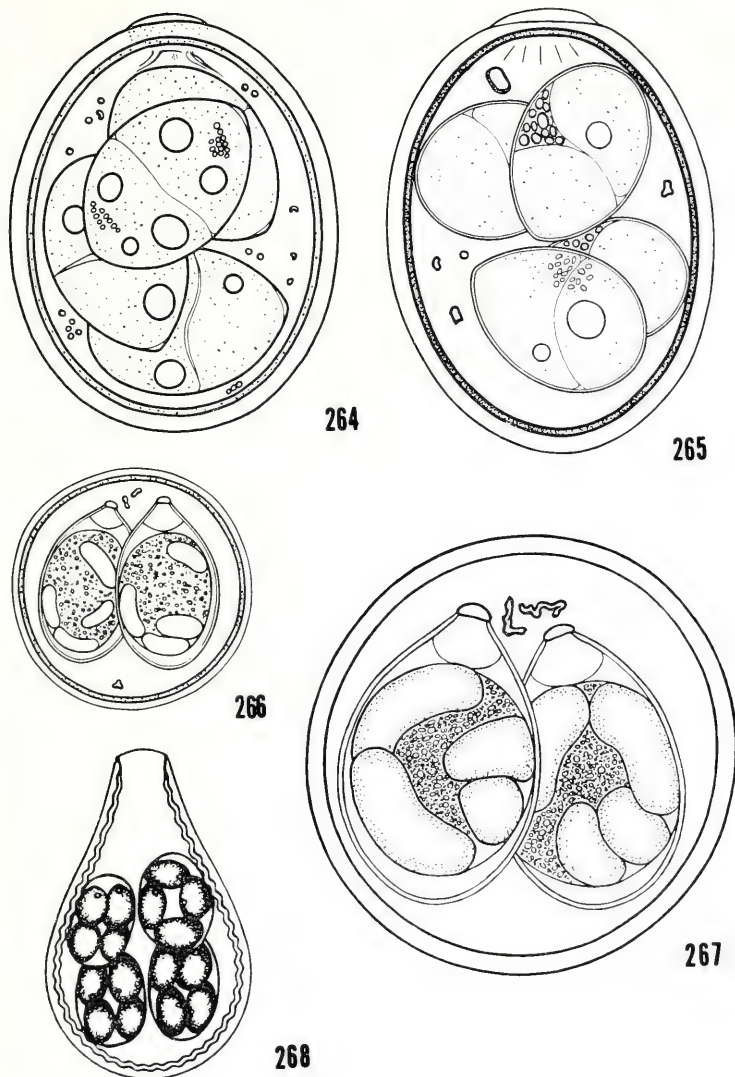


PLATE 60

Figs. 264-265. *E. crandallis* Honess, 1942. Fig. 264. Sporulated oocyst from *Ovis aries* (from Kamalapur, 1961). X 2379. Fig. 265. Sporulated oocyst from *Capra hircus* (from Levine, Ivens and Fritz, 1962). X 2379.

Fig. 266. *Isospora* sp. Shah, 1963 from *Ovis aries* (from Shah, 1963). X 1739.

Fig. 267. *Isospora* sp. Levine and Mohan, 1960 from *Bos taurus* and *Bos taurus* — *B. indicus* hybrid (from Levine and Mohan, 1960). X 2379.

Fig. 268. *Wenyonella markovi* Grobov and Ven'-Shun', 1963 from *Capreolus capreolus pygargus* (from Grobov and Ven'-Shun', 1963). X 1144.



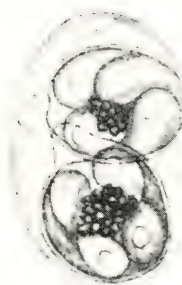
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PLATE 61

Figs. 269-270. *E. brasiliensis* Torres and Ramos, 1939 from *Bos taurus* (from Marquardt, 1959). Fig. 269. Freshly passed oocyst. Fig. 270. Sporulated oocyst with micropylar cap askew.

Fig. 271. *E. intricata* Spiegl, 1925 from *Ovis aries* (from Spiegl, 1925). X 800.

Fig. 272. *I. rangiferis* Yakimoff, Matschoulsky and Spartansky, 1937 from *Rangifer tarandus* (from Yakimoff, Sokoloff and Matschoulsky, 1936 — cited as *Isospora* sp.).

Fig. 273. *E. yakimoffmatschoulskyi* Supperer and Kutzer, 1961 emend. from *Rupicapra rupicapra* (from Boeh and Lucke, 1961). X 850.

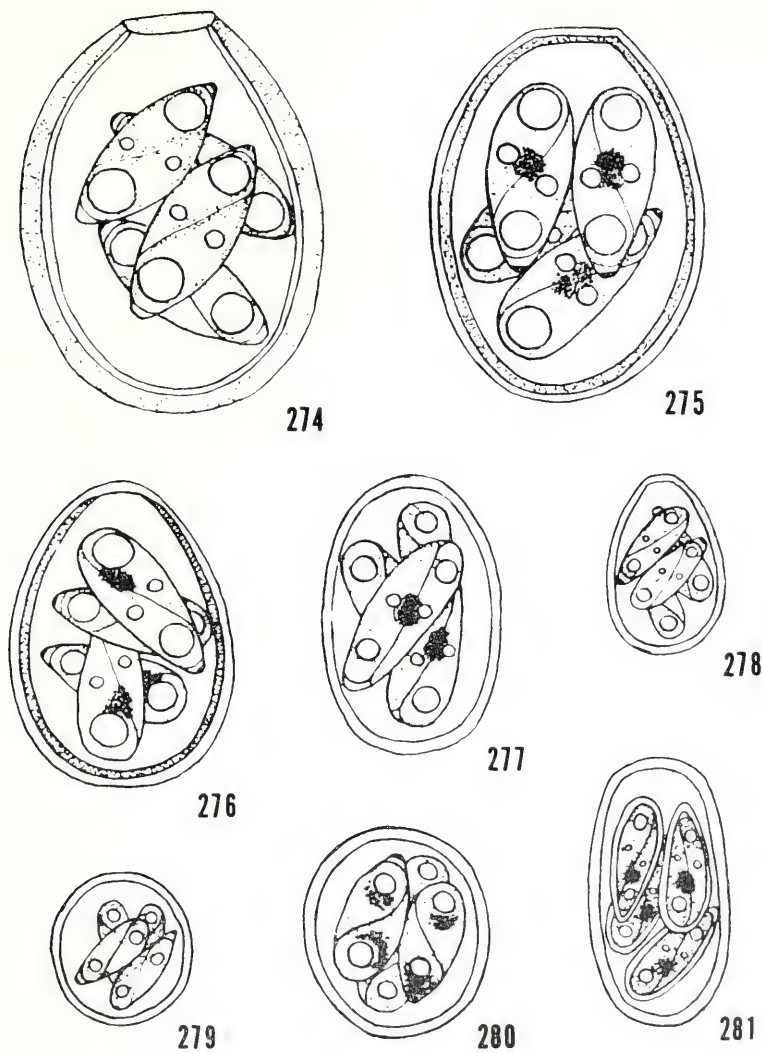
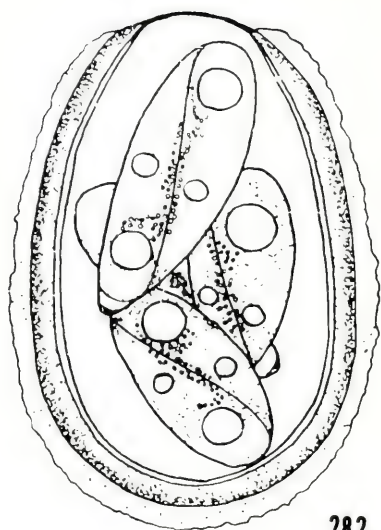
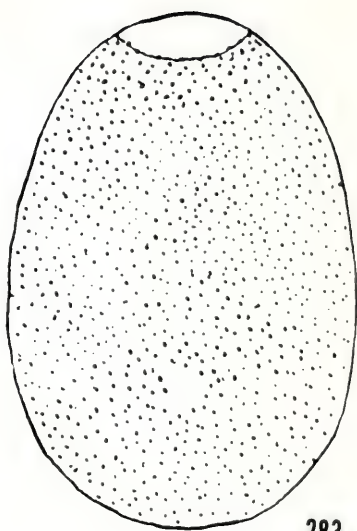


PLATE 62

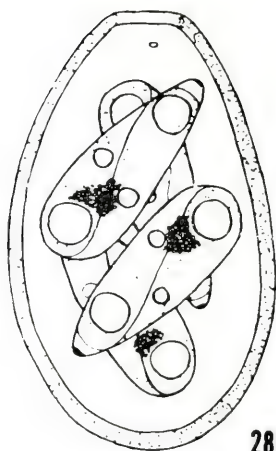
Figs. 274-281. Sporulated oocysts from *Bubalus bubalis* (from Sayin, 1969). X 1500. Fig. 274. *E. wyomingensis*. Fig. 275. *E. canadensis*. Fig. 276. *E. bovis*. Fig. 277. *E. ellipsoidalis*. Fig. 278. *E. alabamensis*. Fig. 279. *E. subspherica*. Fig. 280. *E. zuernii*. Fig. 281. *E. cylindrica*.



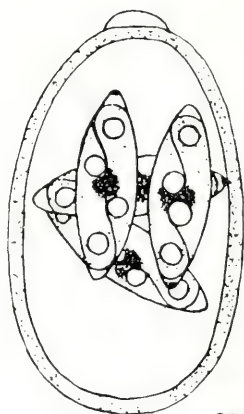
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PLATE 63

Figs. 282-285. Oocysts from *Bubalus bubalis* (from Sayin, 1969). Fig. 282. *E. ankarensis*. X 1650. Fig. 283. Oocyst wall of *E. ankarensis*. X 1700. Fig. 284. *E. auburnensis*. X 1500. Fig. 285. *E. brasiliensis*. X 1500.

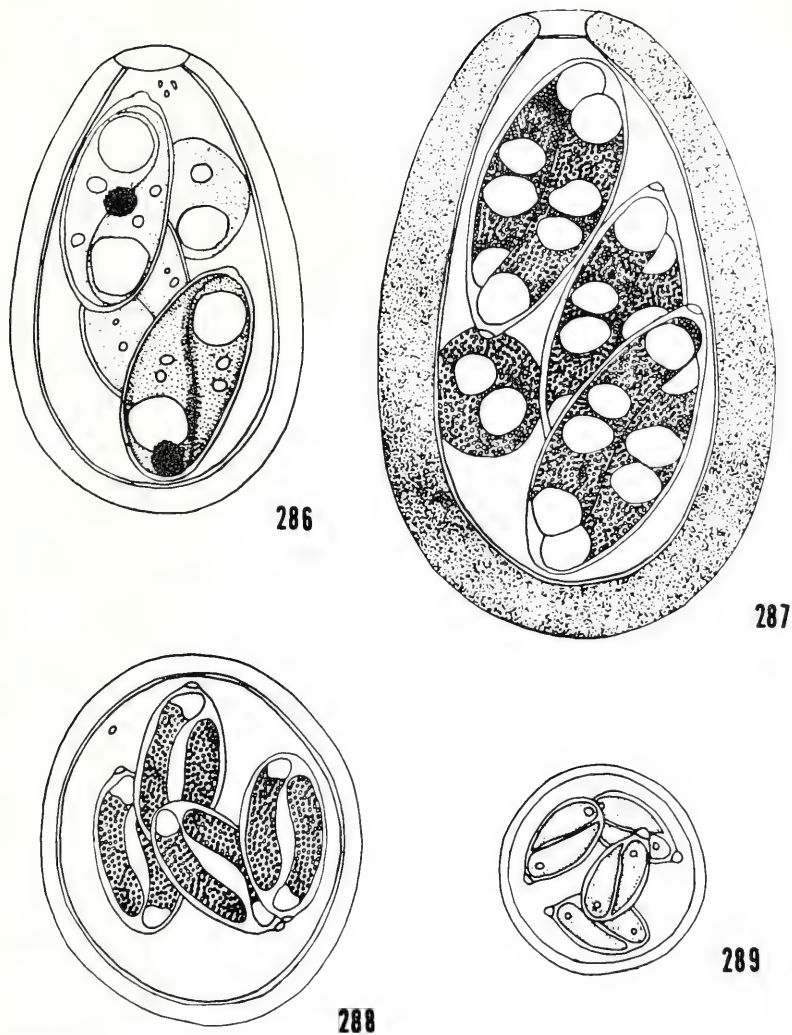


PLATE 64

Figs. 286-289. Sporulated oocysts from *Odocoileus virginianus* (from Anderson and Samuel, 1969). X 2700. Fig. 286. *E. mccordocki*. Fig. 287. *E. virginianus*. Fig. 288. *E. odocoilei*. Fig. 289. *E. madisonensis*.

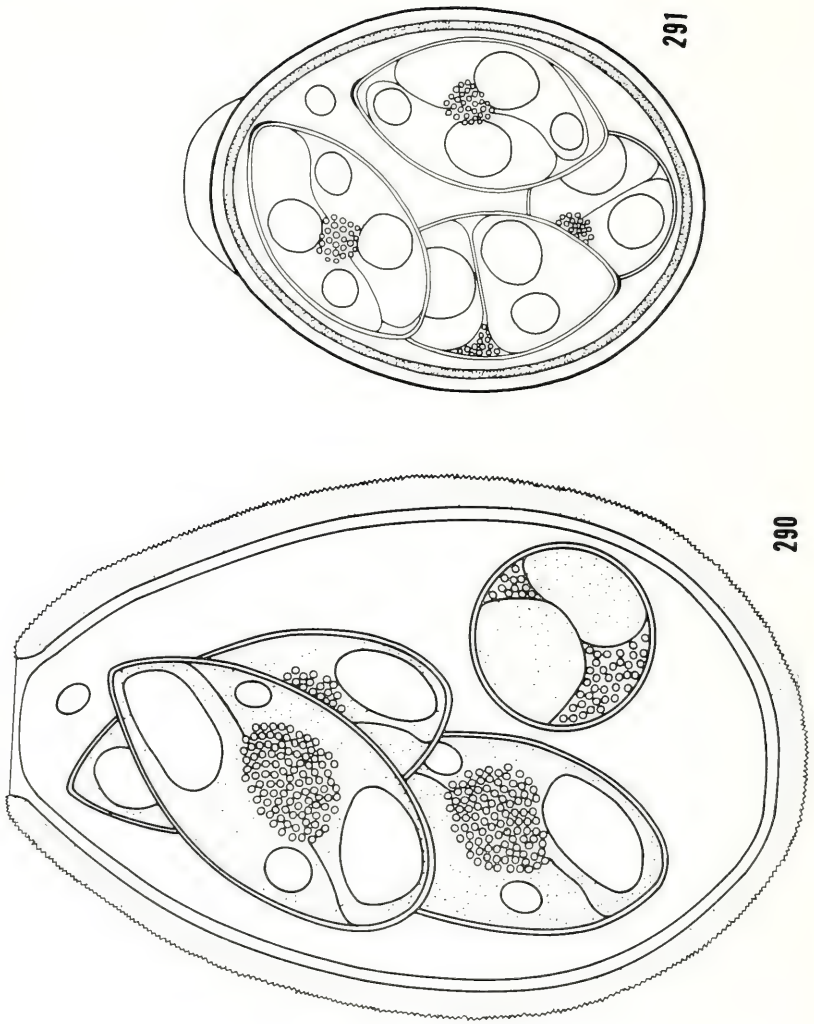


PLATE 65

Fig. 290. *E. ivensae* Todd and O'Gara, 1969 from *Odocoileus h. hemionus* (from Todd and O'Gara, 1969). X 3300.

Fig. 291. *E. gonzalezi* Bazalar and Guerrero, 1970 from *Ovis aries* (from Bazalar and Guerrero, 1970). X 2350.

ADDENDUM

Since this monograph was sent to press, six additional papers have come to our attention:

J. L. Mahrt (1969. Prevalence of coccidia in domestic sheep in central Alberta. Can. Vet. J. 10:176-178) found oocysts of *Eimeria ahsata* in 86%, *E. ovina* in 82%, *E. crandallis* in 88%, *E. faurei* in 52%, *E. granulosa* in 7%, *E. intricata* in 14%, *E. ninakohlyakimovae* in 69%, *E. pallida* in 6%, *E. parva* in 53% and *E. punctata* in 4% of 211 sheep (mostly 3-4 months old) in central Alberta, Canada.

R. Restani (1966. Su di una *Eimeria* parassita di *Ovis aries* L. Parassitologia 8:9-11) described but did not name a new species of *Eimeria* from the sheep in Italy. Its oocysts seem to differ from those of any other *Eimeria* described from his host. They were elongate ellipsoidal, 17-23 by 11-14 μ with a mean of 20.5 by 12.5 μ , with a smooth, colorless or grayish wall composed of a single layer 0.5-1.0 μ thick, with a micropyle without cap 1.5-2.0 μ wide, no oocyst polar granule or oocyst residuum, with ovoid sporocysts 7-11 by 4-6 μ with a mean of 8.6 by 5.0 μ , without a Stieda body but with a sporocyst residuum. The sporozoites were 6 by 3.6 μ , with one end rounded and the other pointed, and with a spherical globule at the large end. These oocysts are rather similar to those of *E. pallida*, but differ in having a micropyle and presumably in having only a single-layered wall. Res-

tani did not name this species, and we are not sure enough of its individuality to name it, either.

T. Sivanarayana and A. Venkataratnam (1969. *Eimeria tirupatiensis* sp. n. (Protozoa: Eimeriidae) from the domestic goat (*Capra hircus*). Ind. Vet. J. 46:477-479) described *E. tirupatiensis* as a new species of *Eimeria* from the goat in India. The oocysts were 37-44 by 25-31 μ with a mean of 40.1 by 28.5 μ . They were elongate ovoid, rarely ellipsoidal, with a wall composed of 2 layers, of which the outer was described as smooth and pinkish, about 1 μ thick and the inner brownish and about 1 μ thick (but in the photomicrograph illustrating their report the outer layer appeared dark and the inner one colorless). A micropyle was present and had a cap 1.5-4.0 μ high and 8.5-11.0 μ wide with a mean of 2.2 by 9.4 μ . There were 1-3 oocyst polar granules but no oocyst residuum. The sporocysts were ellipsoidal to ovoid, 11-16 by 9-11 μ with a mean of 14.1 by 9.6 μ , and had a Stieda body and a sporocyst residuum. The sporozoites were 11-16 by 4.5-7 μ with a mean of 13.7 by 5.0 μ ; they contained 2-3 refractile globules. The sporulation time at room temperature was 4 days. This form appears to differ from others reported from the goat; it somewhat resembles *E. christenseni* and *E. ahsata* but its sporocysts have a Stieda body.

J. Gruvel and M. Graber (1965. Quelques résultats d'enquêtes récentes sur la globidiose du dromadaire au Tchad. Note préliminaire. Rev. Elev. Med. Vet. Pays Trop. 18:423-428) found oocysts of what they called *Globidium cameli* Henry and Masson, 1932 in the feces of 14 out of 204 dromedaries in Chad. Since they did not describe the oocysts, it is impossible to be sure what species they were dealing with.

A. Mantovani (1966. *Eimeria dorcadis* n. sp. (Protozoa: Eimeriidae) parassita di *Gazella dorcas* (L.). Parassitologia 8: 13-15) described *E. dorcadis* n. sp. from a gazelle *Gazella dorcas* from Cirenaica, North Africa, brought to Italy. Its oocysts were yellowish, ovoid (illustrated as ellipsoidal), 26-31 by 15-20 μ with a mean of 29.0 by 18.2 μ , with a smooth wall 1.0 μ thick apparently composed of a single layer, and without a micropyle, oocyst residuum or apparently oocyst polar granule. Its sporocysts were 21-26 by 8-11 μ with a mean of 23.0 by 9.4 μ , and had a sporocyst residuum but apparently no Stieda body. The sporozoites were comma-shaped, 8-12 by 2-4 μ with a mean of 10 by 3 μ . Sporulation time in 5% potassium dichromate solution was 2-3 days. Mantovani was unable to transmit this species to a young goat and a lamb. It is different from any other species reported from gazelles, and we consider it valid.

R. Restani (1968. Ricerche sui coccidi presenti in camosci (*Rupi-*

capra rupicapra L.) della zona di Cortina d'Ampezzo. Parassitologia 10:37-46) studied the coccidia of 31 chamois *Rupicapra rupicapra* from 2 herds in Italy. He found *E. rupicaprae* in 30, *E. riedmuelleri* in 26 and *E. yakimoffmatschoulskyi* in 1. The descriptions of these species which he gave were in agreement with those reported by others. He was unable to infect a Tibetan dwarf goat, a lamb and a calf with *E. rupicaprae* or *E. riedmuelleri*. He could not infect the calf with *E. yakimoffmatschoulskyi*, but said that he did infect the goat and lamb. The goat became positive 8 days after inoculation and remained so for at least 22 days. The lamb also became positive 8 days after inoculation and remained so for 10 days. However, it is uncertain to us whether he was really dealing with *E. yakimoffmatschoulskyi* or with some other species native to the goat and sheep, since he gave no details.

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